CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 33 ISSUED JULY 15, 1947 No. 3

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CALIFORNIA FISH AND GAME is a publication devoted to the conservation of wildlife. It is published quarterly by the California Division of Fish and Game. All material for publication should be sent to Carlton M. Herman, Editor, Division of Fish and Game, Strawberry Canyon, University of California, Berkeley 4, California.

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PISMO CLAM INCREASE [1]

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Beginning in 1919 a systematic survey of the Pismo clams *(Tivela stultorum)*, on the beach near the town of Pismo has been made each year by the Bureau of Marine Fisheries. The first portion of this study was carried out by Weymouth (1923). Later additions were made by Herrington (1930) and other members of the staff of the California State Fisheries Laboratory. The present article adds information gathered since the last report and indicates the present conditon of the clam population.

Each year sections have been made across the beach in three locations some distance apart. The section consisted of a trench 16 centimeters wide and 20 centimeters deep made across the beach and extending from high tide to as low as it was possible to dig during one of the lowest tides of the year. The sand from this trench was forced through a screen of one-fourth inch mesh to make sure no small clams would be missed. The locations of these sections were 100 yards north of the pier at Pismo (Pismo section), 1.1 miles south of the pier (Oceano section), and one-half mile south of the north boundary of the clam refuge (Le Grande section). The number of clams taken in these three sections are given by age groups in Table 1. Data for the period 1942 to 1945 are missing as there was insufficient staff available to carry on this work during the war. Although the total number of clams found in 1946 was greater

TABLE 1

Number of Clams by Age Groups Taken in the Three Sections Dug Each Year on Pismo Beach

	Age in Years									
Year	*0*	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VII+*	*Total*
1925	23	265	6	17	5	5	7			328
1926	53	15	87	3	5	1		1		165
1927	38	61	27	23		1				150
1928	6	32	40	24	15					117
1929	472	5	23	23	15	7				545
1930	360	188	5	4	6	4	3			570
1931	885	157	58	2	3	3	1			1,109
1932	44	277	125	99	28	3	2			578
1933	199	38	122	99	110	52	25	2		647
1934	1	70	23	81	81	31	8	4	1	300
1935	770	6	57	15	69	41	23	6	2	989
1936	144	368	3	45	9	56	28	17	12	682
1937	747	102	247	8	19	7	32	15	2	1,179
1938	9	233	96	175	7	11	9	6	2	548
1939	24	4	54	75	143	2	5	4	7	318
1940	25	34	11	19	29	85	11	8	30	252
1941	19	6	7	1	2	6	23	3	13	80
1946	607	167	57	204	220	51	21	8	13	1,348

[1] Submitted for publication, March, 1947.

than in any previous year in which a census was taken there is no reason to believe that the clam population is near the total that the beach could support. Reports of persons who were on the beach before extensive digging had depleted the natural stock state that once there were many more clams on the beach than at present. Beaches at other locations where these clams are found also indicate that the saturation point has not been reached at Pismo.

As has been pointed out in former publications and is evident from Table 1, the number of young clams less than a year old, O age, is quite variable. In some years sets have been heavy, in others very sparse. Outstanding sets occurred in 1929, 1930, 1931, 1935, 1937, and 1946. In the years 1928, 1934, and 1938 the numbers of young clams were negligible. It would appear that the size of any year's spawning is not mainly determined by the number of adult spawning clams on the beach. The good sets of 1929 to 1931 followed an interval when the number of clams of all sizes was at low ebb, whereas the poor sets of 1934 and 1938 and the mediocre sets of 1939 to 1941 followed years when mature adults were again plentiful.

The variation in the number of mature adults is shown more clearly in Table 2. Here are listed by sections the total numbers of clams four years and older found each year in which a sample was taken since 1925. Following the good sets of 1929 to 1931 the number of adult clams reached a peak in 1933, remained at a fairly high level through 1936, and then decreased to low level in 1938. Good sets in 1935 and 1937 again produced increases in 1939 and 1940. This correlation between the numbers of adults in a population and the success or failure of spawn survival is characteristic of a population exposed to heavy exploitation by man. Such is true of the Pismo clam where individuals are removed

TABLE 2

Number of Clams Four Years and Older Found in Each Section Dug on Pismo Beach

Year	*Section*			
	Pismo	*Oceano*	*Le Grande*	*Total*
1925	4	8	4	16
1926	0	3	2	5
1927	0	0	0	0
1928	12	2	2	16
1929	11	3	8	22
1930	2	3	8	13
1931	2	3	2	7
1932	15	10	8	33
1933	80	72	37	189
1934	53	34	38	125
1935	47	42	52	141
1936	24	19	79	122
1937	15	18	42	75
1938	15	9	11	35
1939	91	26	44	161
1940	50	39	74	163
1941	9	5	33	47
1946	169	75	69	313
Average	33.3	20.6	28.5	82.4

from the beach as soon as they have reached the legal size of 127 centimeters (five inches) and in many instances before that time.

The large number of clams found in 1946 is of special interest since the increase occurs not only among the O group clams but also among the larger older clams. The numbers of three- and four-year olds were greater than at any time in the previous 17 years in which a census was made. Part of this increase may result from good sets in 1942 and 1943 but if that were the only cause those sets would have had to have been greater than any previously known. It seems reasonable to assume, therefore, that part of the increase was brought about by decreased digging during the war years. For defense reasons the public was not allowed on the beaches at night and fewer people were able to take annual vacations or to travel any distance when a vacation was possible.

An 18-year average of the number of clams over age three is given by sections in Table 2. Since 1933 the numbers of older clams have increased as the result of several successful spawnings. For the combined sections the 1946 total is more than three times the average. With the exception of 1933, in none of the previous years has the total reached twice the average. For the Pismo and Oceano sections the 1946 numbers exceeded the average by 5 and $3\frac{1}{2}$ times respectively. In the Le Grande section the increase was slightly more than twice the average. This section lies in an area closed to clam digging and should not reflect an increase in the number of older clams which might have occurred with less digging during the war. These differences between the open and closed portions of the beach further suggest that the large number of clams found in 1946 resulted to some extent at least from protection afforded the beach during the war. It will be of interest to determine how long this larger population can be maintained, especially as the number of people visiting the beach is increasing each year.

A parallel increase of the Pismo clams has been noted during the fall and winter of 1946-47 on the beaches in the neighborhood of Long Beach and Seal Beach. These clams, however, comprise younger individuals of less than four years. No census has been made in this area but presumably the increase has resulted from good protection during the war when diggers could not frequent the beaches.

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THE STATUS OF PINE MARTENS IN CALIFORNIA[1]

By Howard Twining and Arthur Hensley

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California Division of Fish and Game

The pine marten, also called American sable by virtue of its close relationship to the rare and valuable sable of the Old World, is much sought by a few hardy trappers in the higher mountains of California. The marten has a body about the size of a slender house cat, and like other members of the weasel family, to which it is affiliated, it has short legs. The tail is bushy and the head broad, tapering sharply to a pointed nose. It is rich golden-brown in color except for a vivid orange patch on the throat and chest. Furriers work the skins into scarves and neckpieces or occasionally use them as trimming for high quality coats and wraps. Marten fur usually sells for two or three times the price of mink.

Grinnell, Dixon and Linsdale (1937) describe two subspecies of pine marten from California: the Sierra Nevada pine marten *(Martes caurina sierrae),* which occurs in the Sierra Nevada and Cascade Mountains and across to the Trinity, Salmon and Marble Mountains; and the Humboldt pine marten *(M. c. humboldtensis),* a slightly smaller and darker subspecies found in the northern Coast Ranges of California (Fig. 40).

If the pine marten were a denizen of the lowlands of California, its valuable pelt would presumably have encouraged too-intensive trapping, resulting in serious reduction in its numbers, much as once occurred to the beaver and sea otter. Its haunts, however, are the forests of the higher mountains and the rockslides and moraines of the Arctic-alpine zone. Roads into marten country are usually blocked by snow during trapping season and a marten trapper must be equipped to live in a rigorous climate and usually to trap in steep, rugged country. Consequently, much marten country is not trapped and the species has been able to survive.

For many years some fur buyers, trappers, and other people interested in the welfare of the fur-bearing animals of California have been concerned over an apparent scarcity of martens and have recommended complete protection for the species in California. Another recommendation made by certain trappers was that the season on marten be shortened in order to protect the females which, they said, run more in January and February and thus are more liable to be caught at this season.

In order to study the advisability of putting the above two recommendations into effect, a study of pine martens was included as part of a general survey of the fur resources of California.[2]

Among those who have favored a closed season on marten in California are Grinnell, Dixon, and Lindsdale (1937, p. 206), who state:

[1] Submitted for publication March, 1947.
[2] Federal Aid in Wildlife Restoration, Project California 5-R. A Survey of the Fur Resources of the State of California.

"Reports of the trappers of California show a marked decline, amounting to fully 75 percent, in the number of martens trapped in a four-year period. The reported catch for each of these years is as follows: 1930, 452; 1921, 227; 1923, 137; 1924, 121. This decrease is not believed to be

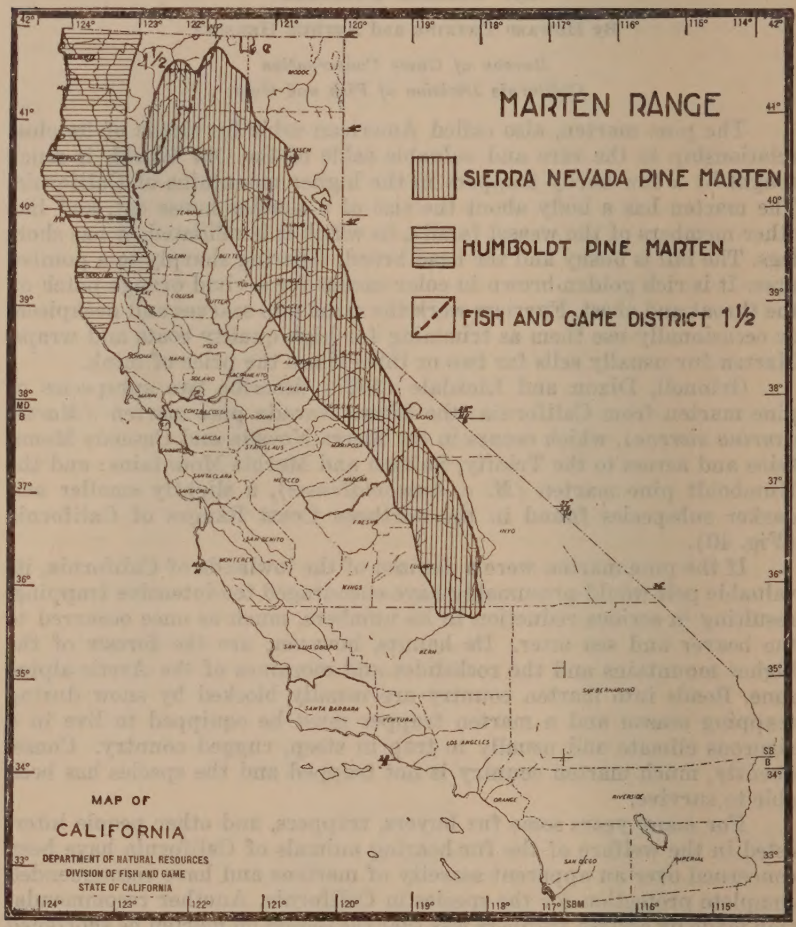

FIGURE 40. Map showing distribution of pine martens in California, and area closed to trapping

a part of any natural periodic fluctuation such as has been reported of this and other mammals elsewhere, because the data at hand indicates that the number of martens living in a general area in California usually does not vary much from year to year; on the contrary, it is probably caused by overtrapping. If this species continues to decline in numbers, and if efforts are not made to give it more adequate protection, in a short time it will be scarce or entirely absent in the State except in such protected areas as national parks."

The catch records quoted above were taken from reports that licensed trappers are required to make annually to the California Fish and Game Commission. A comparison of the above figures with those received for the five years previous to the termination of this study seems significant:

Year	*1937*	*1938*	*1939*	*1940*	*1941*	*1942*
Number marten trapped	129	200	295	510	402	543

If, as the above-mentioned authors assume, catch records can be relied upon to indicate the status of an animal population it would seem that the marten population as a whole recovered from its temporary conditon of depletion and there was no need for a statewide closed season.

In the course of the study 41 marten trappers were interviewed personally by the authors. All trappers who caught marten in the winters of 1940-41 or 1941-42 were furnished questionnaires and requested to record their catch by sex for each month of the season. Certain trappers had informed us that they thought their lines caught more females in January and February because females run more in the breeding season. If it were found that the proportion of females in the catch rose sharply in these months an early closing of the marten season might have been recommended to protect the breeding stock.

A tabulation of results from the questionnaires (Table 1) shows that males in the catch outnumbered females in every month of the season. There was an exceptionally high proportion of males caught in December of both years.

TABLE 1

Data From Marten Questionnaires

	Nov.		*Dec.*		*Jan.*		*Feb.*	
	40-41	*41-42*	*40-41*	*41-42*	*40-41*	*41-42*	*40-41*	*41-42*
Days trapped	115	184	358	592	477	476	370	220
Marten caught	26	58	69	109	81	69	50	49
Days per marten	4.4	2.9	5.2	5.0	5.9	7.3	7.6	4.5
Male	16	24	48	60	36	32	19	24
Female	10	21	21	32	29	27	12	21
Unsexed	--	13	--	17	16	10	19	4
Males per 100 females	160	114	229	187	124	118	158	114

	1940-41	*1941-42*
Average length of line	8.7 miles	8.8 miles
Average number of traps used	48	45
Number of trappers answering questionnaire	23	26
Number of trappers reporting their catch	54	49
Total number of marten reported	428	551
Average price paid per pelt by fur buyers	$15.64	$14.87

There is an unexplained peculiarity in marten breeding habits which should be pointed out at this time. Some light is thrown on this by Ashbrook and Hanson (1930) who found that the mating season for pine martens in captivity is in July and August. Further investigations by Markley and Bassett (1942) verified these findings and set the period of gestation at 259 to 275 days. This seems exceptionally long for an animal the size of a marten. Further study is needed on this and related species to clarify our knowledge of their breeding habits.

The uteri of eight female marten taken in trapping season were examined by the writer but no sign of pregnancy could be detected. Similar observations are reported by Grinnell, Dixon and Linsdale (1937, p. 198) and, in the case of the spruce marten and sable, by Schmidt (1934). Evidently noticeable embryonic development does not begin until late February or thereafter.

If these facts are true, namely that breeding takes place in summer, and that noticeable embryonic development does not start until the next spring, then trapping does not interfere with the breeding season nor impose a hazard on the females heavy with young.

Markley and Bassett (1942) found that marten differ in their mating habits from other members of the weasel family in that mating does not take place until the female is over a year old, and in over 50 percent of the cases not until the age of two or three years is reached. The size of the average marten litter is only three as compared with five or six for mink. It can be expected then that this low reproductive potential would result in slow recovery of a depleted stock.

In the course of the study particular attention was given to the status of the Humboldt pine marten of northwestern California. Trappers told us that martens in former days ranged as far south as Hull Mountain in Lake County and Fort Ross in Sonoma County. Martens have not been taken in Lake or Sonoma Counties for many years and recent records are scarce from Mendocino County. A few martens remain on the high ridges of Humboldt and Del Norte Counties and the occasional trapper willing to fight heavy brush and down timber in remote country can occasionally catch one. In 1941 the six trappers who took martens in these counties caught an average of two apiece. In 1942 the eight trappers who took martens in these counties caught an average of two martens apiece.

This apparent depletion of the Humboldt pine marten in the coastal ranges prompted a recommendation to the Fish and Game Commission that the season be closed in this vicinity. Accordingly, in 1946 the commission closed the season on pine marten in District No. 1½, which includes all or parts of Del Norte, Humboldt, Siskiyou, and Trinity Counties. (Fig. 40.) Very few trappers will be affected by this closure and if it results in the repopulation of the depleted marten range the regulation will have served a worthy purpose.

Summary

1. The pine marten is found in the higher mountains of California; its valuable fur encourages trappers to seek it in the remote country where it lives.

2. People interested in the welfare of fur bearers have made two recommendations for management of marten: (1) that the marten season be closed in California, (2) that the season be closed early in order to protect the females which they believed are caught in greater numbers in January and February.

3. Results of an examination of trapping records of past years plus a series of 41 interviews with marten trappers indicated that the marten population except in the north coast portion has not suffered serious depletion in California. A state-wide closed season is not recommended.

4. Information from questionnaires shows that males in the catch outnumber females in every month of the season. The mating season for marten is in July and August. Noticeable embryo development does not start until after February. Early closing of the season for pine marten is not recommended.

5. A shrinking of the original range of the Humboldt pine marten of the Coast Ranges in northwestern California was indicated and reports of catch suggested depletion of the marten population in this area.

6. Upon the recommendation of this project the Fish and Game Commission in 1946 closed the season on pine marten in District 1½ (Del Norte, Humboldt, Siskiyou, and Trinity Counties).

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ECOLOGY AND LIFE HISTORY OF THE CALIFORNIA GRAY SQUIRREL

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The gray squirrel (*Sciurus griseus* Ord) in California inhabits forested areas west of the Sierra Nevada divide from Oregon to Lower California. There are three subspecies within the boundaries of the State; *anthonyi,* in the Southern California mountains; *nigripes,* in the coast belt south of San Francisco Bay to San Luis Obispo County; and *griseus,* over the Sierra and in the Coast Ranges north of San Francisco Bay.

This squirrel is found chiefly within the Upper Sonoran and Transition life zones, extending locally into the lower Sonoran and up into the Canadian. In spite of the wide distribution of this squirrel only a few life history and ecology references occur in the literature. The present paper records data gathered during a six-year period between November, 1940, and July, 1946, on the subspecies *griseus.*

Areas Studied

Many observations were made throughout the State within the range of the species, but most of the work was done in Butte County, particularly in Bidwell Park near Chico. This park comprises 2,400 acres of naturally wooded land along Big Chico Creek, and extends from the floor of the Sacramento Valley well up into the foothills. The park lies in the Lower Sonoran and is characterized by virginal growths of such trees as western sycamore (*Platanus racemosa*), Fremont cottonwood (*Populus fremontii*), valley oak (*Quercus lobata*), and California black walnut (*Juglans hindsii*). In this life zone the two latter trees furnish the greater part of the food of the squirrels. Certain botanists claim the black walnuts were introduced into this area by the early settlers, but there is considerable evidence that they became established around certain old Indian camps long before the advent of the white man. In the foothills the park lies in the Upper Sonoran life zone, and trees are not nearly so dense as they are in lowland groves of valley oaks, sycamores, and cottonwoods. Important foothill trees include the digger pine (*Pinus sabiniana*), blue oak (*Quercus douglasii*), interior live oak (*Quercus wislizenii*), and scrub oak (*Quercus dumosa*).

In other counties, most of the observations were made at different places in the transition life zone where chief food trees were yellow pine (*Pinus ponderosa*), white fir (*Abies concolor*), Douglas fir (*Pseudotsuga taxifolia*), sugar pine (*Pinus lambertiana*), big tree (*Sequoia gigantea*), redwood (*Sequoia sempervirens*), and California black oak (*Quercus kelloggii*).

Methods

The time-area method of Goodrum (1940) was used, with slight adaptations to fit local conditions, to ascertain populations of squirrels. The observer carried at all times a good pair of 8 x 30 binoculars and

any seemingly significant observations were recorded on the spot. A 6.31 acre area was selected in Bidwell Park for special intensive daily study during March and April, 1945. Here natural food-producing trees were supplemented by certain introduced species. The area was surveyed and all important trees were located on a map with the aid of a plane table. Eight mature gray squirrels were determined by markings distinguishable with binoculars, and their activity on the area was followed daily.

FIGURE 41. A riparian association of valley oaks (*Quercus lobata*), western sycamores (*Platanus racemosa*), California black walnut (*Juglans hindsii*), and California wild grapes (*Vitis californica*), in the Sacramento Valley which supports a large population of California gray squirrels.

The individual home ranges of these squirrels and the territories of two of them were plotted on the map. The areas of the home ranges and territories were computed with a planimeter. The home range and territorial concepts used in this study are essentially those described by Burt (1943). Outlines of the home ranges and territories were represented by connecting points on the periphery of each of the areas. This representation, as Burt pointed out, indicates slightly more or less than the actual area. Observation trips were made at various times of the day under varying conditions of weather, each trip lasting about one and one-half hours. Records made when it was difficult to classify the day as, "clear," "cloudy," or "rainy," were discarded. The Beaufort system of indicating wind velocity was used.

Farther up stream in the park another area was selected, because of natural conditions that prevailed, for a study of habitat preference (Fig. 41). A trail closely following the stream for 1.7 miles passed through a riparian habitat including numerous large sycamores, cottonwoods, alders (*Alnus rhombifolia*), and festoons of California wild grapes (*Vitis californica*) suspended from the tops of the trees. These, with several species of undergrowth shrubs, provided excellent nesting sites, cover from enemies, and protection from strong winds. The return trail paralleled the stream 200 yards distant through a pure stand of valley oaks. In this habitat there was little undergrowth to provide cover and wind protection, and there were few holes in the trees suitable for nesting sites. In season the mast production was enormous. The method used in making observations here was to walk slowly over the 3.4 miles of trail, stopping at frequent intervals to look and listen.

Activity and Behavior

Seventy-four trips were made between dawn and dusk on the 6.31 acre plot in Bidwell Park during March and April, 1945. More squirrels were seen in the early morning hours than at any other time. About half as many were observed per hour after 4 p.m. as were seen per hour before 10 a.m. These findings (Table 1) differ from those reported by Goodrum (1940) on *Sciurus carolinensis*, which practically ceases activity after 9 a.m. but becomes active again late in the afternoon. None of the 325 squirrel observations was made before sunup. Although 14 observation trips extended from dawn to dusk only two squirrels were observed to

TABLE I

Daily Activity During March and April, 1945, in Bidwell Park

	Squirrels observed from—				
	Dawn to sunup (about 7 a.m.)	*Sunup to 10 a.m.*	*10 a.m. to 4 p.m.*	*4 p.m. to sundown (about 7 p.m.)*	*Sundown to dark*
Observation trips	14	60	60	60	14
March	0	65	93	19	0
April	0	51	63	32	2
Total number of squirrels observed per hour in each category	0	38.6	26	17	0

be active after sundown. One of these spent the night lying on a limb after another squirrel had chased it away from a tree-hole it had attempted to enter. Goodrum's observations regarding regular activity of the eastern species on moonlit nights apparently do not apply to *Sciurus griseus.*

Although notes were kept on ecological factors that might conceivably affect the behavior and population of the squirrels, weather relationship was especially noted for the two months during which daily observation trips were made. A Beaufort 6* was the strongest air movement noted during the two months period. An observation trip in the riparian and oak habitats during a Beaufort 6 north wind revealed five squirrels on the ground or in the low shrubbery of the riparian habitat where air movement could scarcely be felt. None was seen in the oak habitat where the wind was strong, even close to the ground. The animals, by choosing protected places, were found to be about equally active under all conditions regardless of the wind (Table 2). Although there was no opportunity to observe behavior in very strong wind, there was no noticeable reduction in activity in winds of moderate velocity as described by Goodrum (1940).

TABLE II

Response to Weather During March and April, 1945

	Clear	*Cloudy*	*Rainy*	*Wind Beaufort 0-4**	*Wind Beaufort 4-6**
Observation trips	46	11	10	66	12
Squirrels observed	156	54	30	329	36
Average squirrels per trip	3.4	4.9	3.0	4.5	3.0

A few more squirrels were seen on cloudy days than on a corresponding number of trips made on clear or rainy days (Table 2). In the spring months the squirrels were more active in the warm, moist, and less windy air than immediately after the passing of a cold front.

Several squirrels were observed moving about in moderate rain storms. They frequently jumped, shaking the feet and tail to free them from water. When eating in the rain they curl the tail up over the head and body in such a way that the water runs off the long tail hairs without wetting the animal. After being active in rain or morning dew they lick themselves extensively before retiring into a nest.

Although the California gray squirrel may be active at any time between sunup and sundown, there may also be long periods of rest during the day. Resting periods are usually taken in a tree-hole. On very hot days the animals become noticeably less active. They were frequently seen spread out on some shady limb with the legs and tail hanging over the edges, and the chin resting on the limb. Gray squirrels usually retire to a tree-hole at night. Except when the young are in the drays, it is doubtful if outside nests are used for nocturnal sleeping. When asleep a captive squirrel lay on its side with its nose and forefeet pressed lightly against its lower abdomen with the large tail spread over all the body. It was difficult to awaken this animal.

* A classification of wind velocities: Beaufort 4—13-18 miles per hour; Beaufort 5—19-24 miles per hour; Beaufort 6—25-31 miles per hour.

There was considerable opportunity to observe the acuity of the senses and behavior of the California gray squirrel. A young captive squirrel taken from the nest shortly after the eyes were open exhibited many interesting traits of behavior. Apparently this animal could not see even though the eyes were open, for it located the medicine dropper with which it was fed by trial and error movements with forefeet and head and possibly by smell. Later an opaqueness developed in the cornea, and it became obviously blind. It could hear a whistle and would cease activity for a short time when the sound was made. When the dropper was removed for refilling the squirrel would utter a nasal ku-ku-ku-ku-ku until it began to suck again.

Sense of sight is only fairly keen in gray squirrels. On one occasion the writer attracted the attention of an animal at a distance of 50 yards by waving his arms. Strange motionless objects in the home range are frequently seen at a distance of as much as 50 feet. Sense of smell seems fairly well developed. Squirrels were observed on several occasions to come to the ground and, after sniffing over several square yards, dig up walnuts that had been buried more than one and one-half inches below the surface. Four small pebbles and a pecan were wrapped separately in pieces of heavy paper and placed on a log under a tree frequented by the gray squirrels. A similar set was made a the base of another tree with two pebbles and two pecans, one of the latter being buried. Twenty-four hours later only the papers bearing the pecans above the ground were unwrapped, and the contents apparently taken by the squirrels. None of the pebbles was touched.

Adult gray squirrels made at least two kinds of sounds that aid in locating them in the dense foilage. A series of coughs or barks. uttered rapidly at first but becoming progressively slower as the series draws to an end, are frequently heard when an animal has been frightened or becomes suspicious. These *cha-cha--cha---cha----cha-----cha* calls can be heard on quiet days for 200 yards or more. Sometimes the calls will be given every few seconds for an hour, and, in most cases, the cause for the alarm can not be ascertained. At the instant of giving the call one of the front feet is audibly vibrated against the limb. Sometimes when alarmed a squirrel will vibrate the forefeet without barking. Squirrels may frequently be located in the woods by the noise they make while gnawing. A squirrel gnawing on a black walnut can be heard at a distance of 75 yards.

Although gray squirrels are almost never found away from a tree in the areas studied by the author, they spend a great deal of time on the ground and may travel 250 yards before climbing a tree. Not infrequently tree-top routes 75 to 100 yards long are used to cross streams and to get from place to place when trees are sufficiently abundant. Although quite at home in trees, they lack the arboreal agility of the Douglas squirrel *(Tamiasciurus douglasii)*. On one occasion a gray squirrel was seen to fall from a tree by accident. The dead limb along which it ran broke just as the animal was preparing to leap from it into a near-by tree, the squirrel and the limb falling separately to the ground some 50 feet below. The animal was stunned for a few seconds before it rushed to the base of another tree and climbed it.

On the ground the gray squirrel is not a rapid runner, but will, nevertheless, frequently pass by trees in order to reach its den tree.

One animal ran through three inches of snow past many other trees a distance of 186 feet to its den tree. One leap down a slope measured six feet eight inches. Only once was a squirrel seen out of sizable timber; this one was in chaparral near Tollhouse, Fresno County.

Relations to Plants

Unlike the Douglas chickaree, the California gray squirrel buries acorns and nuts in the ground singly and never in large caches; this practice no doubt contributing materially to reforestation. On many occasions gray squirrels were observed to collect and bury acorns of the valley oak outside the perimeter of the spread of the parent tree. These acorns frequently are not recovered and, because they are in the open, may produce healthy little trees (Figure 42). Sometimes certain small

FIGURE 42. Young valley oaks (*Quercus lobata*) growing outside the spread of the parent trees from acorns planted by California gray squirrels in the Sacramento Valley.

areas are favored for food storage. On one occasion 22 young black walnut trees were counted within a 50-foot circle. The parent tree from which the nuts were collected, presumably by the squirrels, was 152 feet away. Probably because squirrels rarely frequent them, large acorn-bearing oaks isolated from the rest of the woods having no such growth of young trees outside their perimeter and rarely have any beneath them.

Sometimes gray squirrels damage certain trees either directly or indirectly. Fritz (1932) describes damage done to young redwood trees by gray squirrels removing the bark near the top of the tree in order to reach the succulent layer beneath it. Grinnell and Storer (1924) pointed out that large kitchen middens left as they husk the big sugar pine cones at the bases of the trees may be fire hazards (Figure 43). These concentrations of pine scales produce hot fires which cause deep burns in the

trees. However, it is very doubtful whether the damage done to the forests by gray squirrels is significant.

FIGURE 43. A kitchen midden of the California gray squirrel at the base of yellow pine (*Pinus ponderosa*) in Tulare County

Competitors

There is perhaps no animal that causes the California gray squirrel more annoyance than does its competitor, the Acorn woodpecker *(Balanosphyra formicivora)*. Not only do woodpeckers attack squirrels as they garner acorns from the ground beneath trees in the autumn, they continue the feud about their acorn-studded trees at other seasons of the year as well. Squirrels on the ground are sometimes attacked by two or three woodpeckers at one time. The squirrels gain a certain amount of protection by carrying the large bushy tail well above the back. The birds fly into the tail which the squirrel flicks violently. In a tree squirrels are forced to retreat at top speed. Acorn storage trees are frequently guarded by as many as six birds, and although they may be in a direct tree route for the squirrels they are avoided, the squirrels going well around or even coming to the ground in order to pass. On one occasion two gray squirrels were digging for acorns beneath a large Digger pine which contained thousands of acorns zealously guarded by five noisy woodpeckers. The woodpeckers' acorns were all stored more than 20 feet above the base of the tree, and the birds paid no attention to the squirrels on the ground.When one of them jumped a few feet up the tree

trunk, it was vigorously attacked and pursued until it sought safety in another tree several yards away. On another occasion three squirrels were "rushed" by the writer as they were gleaning buried nuts at the base of this same tree. Although all were within six feet of the base of the pine, they scurried to other trees 30 to 60 feet away rather than brave an attack by the woodpeckers. No squirrel was observed robbing a woodpecker's storage tree.

Another animal that causes the gray squirrel considerable discomfort wherever the two occupy the same area is the Douglas squirrel. It was observed once to chase a large gray squirrel over 100 yards, largely on the ground. At Giant Forest, Tulare County, a similar incident was observed. It seems probable that the Douglas squirrel may limit the upward zonal distribution of the California gray squirrel into what would otherwise be suitable habitats.

In some places Beechey ground squirrels (*Citellus beecheyi*) compete with gray squirrels for food. On several occasions ground squirrels were seen to rush at the gray squirrels when the latter came too close to their burrows. Once a ground squirrel prevented two gray squirrels from crossing a stream by stationing itself on a limb along the only tree route over the stream.

Gray squirrels on the ground have been observed to take refuge and climb trees when Oregon juncoes (*Junco oreganus*) gave their alarm calls.

The fox squirrel (*Sciurus niger*) and the eastern gray squirrel (*Sciurus carolinensis*), introduced several years ago from eastern states into the cities of Sacramento, Fresno, San Francisco, and a few other places, generally seem to be unable to leave the cities to compete with the California gray squirrel in its native habitat, although their inability to do so has not been proved for fox squirrels have apparently established themselves in the woods in San Mateo County.

Predators

There are very few known cases of predators catching gray squirrels. Near Palo Alto, Murie (1936) saw a house cat catch a mangy gray squirrel with a nearly hairless tail. The animal was apparently weak and sick. Near Magalia, Butte County, a large freshly killed and partly eaten gray squirrel was found on a fallen tree about four feet off the ground. A goshawk (*Accipter gentilis*) or a horned owl (*Bubo virginianus*) seemed the most likely predator in this thick pine woods. Both red-tailed hawks (*Buteo jamaicensis*) and red-shouldered hawks (*Buteo lineatus*) were observed eating Beechey ground squirrels in regions where gray squirrels were common. It seems likely that at least young gray squirrels would be captured occasionally by either of these hawks. Fitch *et al.* (1946) found remains of two young gray squirrels in 13 red-tailed hawk nests on the United States Experimental Range in Madera County. In two pellets out of 2,094 they found the hair of gray squirrels.

Horned owls were occasionally seen flying at dusk in Bidwell Park where there are many gray squirrels. Although these squirrels rarely are active after sundown, if abroad they would certainly be vulnerable to these large owls.

In the digger pine and yellow pine associations, gray squirrels doubtless fall prey to the gray fox (*Urocyon cinereoargenteus*) and bobcat (*Lynx rufus*). The coyote (*Canis latrans*) is known to eat them (Sperry, 1941). Since these squirrels spend considerable time on the ground and are not rapid runners, they could easily be caught by these large mammals.

Although no factual data are available, in the opinion of the writer it is doubtful if all predators take more than a small percentage of the number of squirrels that are annually killed by automobiles on the highways. They seem to have no ability to recognize the danger of an approaching car.

Parasites and Diseases

There is an old belief among ranchers living in the Sierra foothills that young male gray squirrels are emasculated by the older males. Testes were present in all males examined or observed at close range. Seton (1928) describes instances where the dipterous parasite (*Cuterebra emasculator*) destroys the testes of the eastern gray squirrel. Although unidentified botflies were commonly found living under the skin of the throats of dusky-footed wood rats (*Neotoma fuscipes*), on areas that were occupied also by the California gray squirrels, none was ever found to parasitize the latter animals.

Hubbard (1943) listed four species of fleas as parasites of this species of gray squirrel. The most common species was *Orchopeas nepos* which lives also on the Douglas squirrel and is found over most of the California range of the gray squirrel. Other species were *Orchopeas latens, O. dieteri,* and *Opisodasys enoplus.*

The California gray squirrel is subject to devastating diseases which occasionally reduce their numbers alarmingly. One of these diseases is caused by scabies mite (*Notoedres* sp.) and is first evidenced by a scaly or mangy appearance about the head and neck (Bryant, 1921). This is followed by loss of hair over the rest of the body. Dead squirrels frequently are found at the base of the trees. This disease greatly reduced the squirrel population throughout much of its range between 1913 and 1921. In Bidwell Park, Mr. George Peterson (M.S., 1945) described a great epidemic about 1913, "as eliminating all of the squirrels in the 2,400 acre park." According to Mr. Peterson, "only a very few squirrels remain among the digger pines out of the park on a certain hillside near Cherokee (Butte County) 20 miles away.

That there are possibly other diseases that kill large numbers of squirrels is indicated by the finding of eight mummified bodies showing no evidence of scabies on June 17, 1946, on the 6.31 acre tract in Bidwell Park that was used for the study of home ranges. Assurance was given by a patrolman that the squirrels all died within the two weeks previous, and that no poisoned grains had been spread for ground squirrels. A crippled squirrel from the area was sent, on June 15, 1946, to the Hooper Foundation for Medical Research, San Francisco, for examination. They reported no evidence of intoxication or infection in the specimen. Only three living squirrels were seen on the area in an entire morning, two of which were young. The same area the year before was the home of 11 adult animals most of which could be seen in a similar period of time.

Food

The food which this squirrel was seen to eat was largely seasonal, but stored walnuts and acorns were frequently dug up and eaten even in the spring when many other things were available. Foods that were observed to be eaten included:

Valley oak ---------- *Quercus lobata* (acorns, catkins)
California black oak ---------- *Quercus kelloggii* (acorns)
California black walnut ---------- *Juglans hindsii* (nuts)
Pecan ---------- *Carya pecan* (nuts)
Almond ---------- *Amygdalus communis* (nuts)
Yellow pine ---------- *Pinus ponderosa* (nuts)
Jeffery pine ---------- *Pinus ponderosa jeffreyi* (nuts)
Digger pine ---------- *Pinus sabiniana* (nuts)
Monterey cypress ---------- *Cupressus macrocarpa* (nuts)
Red mulberry ---------- *Morus rubra* (berries)
Silver maple ---------- *Acer saccharinum* (samaras)
American elm ---------- *Ulmus americana* (samaras)
Mistletoe ---------- *Phoradendron flavescens* (berries)
Miner's lettuce ---------- *Montia perfoliata* (leaves)
Common chickweed ---------- *Stellaria media* (flower buds)
Aphis, causing leaf roll in Oregon ash bone ---------- *Fraxinus oregona*

The author obtained no evidence that the gray squirrel robs birds' nest of eggs or young birds although they are reported to do so and they do eat animal food. Aphids and doubtless many other insects are eaten. The head of the femur of a sheep was gnawed by several squirrels; after which it was always cached in the crotch of a tree.

As pointed out previously, individual acorns and nuts are buried in holes dug in the ground, sometimes relatively large numbers in a small area. During fire prevention operations in Bidwell Park, a disc turned up a number of acorns that had been buried by a squirrel recognizable to the author by a scar on its head as one habitually occupying the area. Within half an hour the animal was busily burying the uncovered acorns.

Efforts were made to determine the amounts of food eaten by squirrels on different occasions. Another animal similarly recognized was observed in March to eat seeds from 15 Monterey cypress *(Cupressus macrocarpa)* cones, meats from five black walnuts, and a pecan, and to graze for some time on the buds of chickweed *(Stellara media)*. The feeding period lasted for two and a half hours. Samples of these foods were collected and weighed to ascertain the total mass consumed, which was estimated to be 43.6 grams. In a one hour period in April the same squirrel ate the seeds from 223 silver maple *(Acer saccharinum)* samaras and the meats from two California black walnuts estimated to weigh 51.6 grams. Two lactating female squirrels were observed on different occasions to eat flower buds and leaves of chickweed.

On different occasions squirrels were observed to drink (without lapping) from streams and from knot holes containing water. One was seen to come to the ground to urinate. The oblong fecal pellets are dark brown or black, 2-3 mm. wide by 4-5 mm. long. They are sticky and sometimes adhere to the fur.

Breeding Behavior

The California gray squirrel appears to have but one rutting period a year; this starts in January and continues for some individuals through

May. The peak appears to be reached in February. However, Bailey (1936) reported a lactating gray squirrel in Humboldt County on October 30. This date may indicate two litters a year, but may also represent only a late breeding young female. The rutting period of the gray squirrel is characterized by considerable chasing by both males and females and by the presence of one or more males in the immediate vicinity of a female. Testicles of the males are noticeably enlarged and the scrotal sac is more darkly pigmented than the rest of the under parts. When in *oestrus,* the vulva of the female is swollen and pink in color.

An actual copulation was observed late on the afternoon of March 23, 1945, in Butte County. A female, designated as No. 2, was observed receiving the attentions of two males on March 19, 1945. On March 23, 1945 (about 5:15 p.m.), when the author entered the area the barking of a squirrel was heard about 50 feet up in an oak. Through the glasses this animal was identified as a male. On a nearby limb was female No. 2 licking her vulva. After several minutes the female started off by a tree route to a walnut tree on the other side of the grove. She stopped occasionally to lick her vulva. The male followed slowly about 20 feet behind, barking softly. On reaching the walnut tree she descended it slowly until within a few feet of the ground. When the male overtook her she would pursue him vigorously for a few feet. After several such charges the male rushed after her, and the two went round and round the trunk for several seconds until he overtook her at the end of a small branch about 12 feet above the ground. There was a great tussle and a flourish of tails took place. The male mounted the female dog-like, and in a couple seconds the copulation was completed. In the final tussle the male lost his hold and fell to the ground. The male climbed the tree slowly, but finding the female facing him on a small limb returned to the trunk and bit off chunks of bark which he threw to the ground. After several minutes he descended to the ground found a walnut, and proceeded to eat it. The female, after licking her vulva, descended to the ground, found a nut, and ate it.

The male gray squirrels seem to be very compatible during the rutting season when it is not uncommon to see three or four together, but serious fights sometimes occur. Such a fight was observed in which one of the squirrels received a badly bitten fore-paw which it favored and licked for six days afterwards. After the fight the beaten and wounded squirrel was pursued in a large tree for half an hour before it escaped unseen by its pursuer to another tree. The pursuing squirrel searched the tree in which the fight occurred before giving up the chase.

Nests

The California gray squirrel builds two kinds of nests; those made in tree-holes and those called drays which are built out among the branches of the trees. Both kinds of nests were observed as they were being built. Tree-holes are generally made by a woodpecker or flicker, but may result from decay following the breaking off of a limb. They are most likely to be found in oaks, cottonwoods, and sycamores. Before occupation they are provided with a soft inner nest made of fibrous shredded bark from redwoods, cedar, or pines. Usually the pieces of bark are gathered on the ground, but on one occasion a pregnant female was observed to collect nestbark from a redwood trunk 60 feet above ground.

The piece of bark was held in the mouth while the claws are combed through it to render it soft and pliable.

The outside of the dray is made of sticks about the diameter of a pencil. Such nests are two to three feet in diameter and may or may not be covered over. The inner nest is either made of shredded bark or fine grass. In Chico one dray which was built in a fan palm *(Washingtonia filifera)* was made entirely out of the fibrous material of the palm tree. It weighed 271 grams and was blown from the tree during a windy day. On one occasion a pregnant female was observed daily as she built a dray in the top of a redwood tree. Merriam (1930) found a gray squirrel dray built in a tan oak *(Lithocarpus densiflora)* in Marin County.

Most nest building takes place in early spring before young are born; however, a gray squirrel was seen adding soft sequoia bark to its nest at Giant Forest, Tulare County, in September. Females were frequently seen carrying nest material to their nests after their young were known to have been born.

Young

The gestation period of the California gray squirrel is longer probably than six weeks. Forty-three days after a known copulation, the obviously pregnant, marked female (described above as female No. 2) had not given birth to young. She was not observed associated with male squirrels after the day of copulation although she was seen daily. The gestation period for the eastern gray squirrel is given by Goodrum (1940) as 44 days. From the author's observations, litters range from two to four young. Nine litters studied had one with four, four with three, and four with two young. Young squirrels begin to make their appearance around the nest about the middle of March with the greatest number appearing about the middle of April. Young of late breeders, however, will not appear until the middle of June even in the lowlands.

The young of the California gray squirrel may be born any time between February 1st and the middle of June, regardless of the life zone. Although young squirrels were frequently found in drays, some evidence was obtained to indicate that they are not necessarily born in these outside nests, but are carried there when they become too large for the tree-hole nest, or when the fleas and other parasites become intolerable in the original home.

The youngest squirrels known belonging to this species were reported by Storer (1922). These were taken from a dray in Marin County on April 13, 1919. They were kept for three days. At first only very short hairs showed dorsally on the wrinkled skin, but at the end of the third day the lateral hairs began to show. Storer gives the weights and measurements for these animals 48 hours after they were taken as follows: male, 74.6 grams, total length 205 mm., tail 93 mm., hind foot 34 mm., ear 8 mm., and for the female, 80.0 grams, total length 225 mm., tail 95 mm., hind foot 37 mm., ear 8 mm. The youngest litter seen during the present study occupied a dray in a palm tree in Chico. One of these young squirrels was kept as a captive until it became full grown. Although this young female had its eyes open, as did the other three litter mates, it was blind within a week and remained so for the rest of its life. The most striking features about the animal were the large feet and the very short hair on the tail (Fig. 44).

This squirrel was kept in a cage and fed with the aid of a medicine dropper, milk and honey at first, and, as it became older, nuts and other foods. It was possible to weigh and measure this animal only in the first month after captivity; later, when it was half-grown (adult females average about 675 grams) it was impossible to weigh it satisfactorily. The weights and measurements obtained are presented in Table III.

TABLE III

Growth of a Young Gray Squirrel

	Total Length	*Tail*	*Hind foot*	*Ear (crown)*	*Weight*
Mar. 10, 1945	270mm.	140mm.	58mm.	10mm.	126 grams
Mar. 16	275	142	59	12	135
Mar. 23	306	150	60	18	179
Mar. 31	–	–	–	–	240
Apr. 6	–	–	–	–	270
Apr. 13	–	–	–	–	353

Upon comparing weights of this squirrel with those of the litter described by Storer (1922), which he estimated to be one week old, it would appear that this one was about three weeks old when taken from the nest. At this time there were several well developed instincts, a few

FIGURE 44. A young California gray squirrel approximately 3 weeks old

of which follow: It would scramble wildly with all four feet when held about the body in such a way that it could get no hold with its claws. It would sit squirrel-like and nibble on objects held between the forepaws

even though it would eat only liquids. When not hungry it resented being taken from the nest, would attempt to bite and would utter little bark-like "quaffs." When about two months old it would bark, flick its tail, and vibrate its forepaw. It had no opportunity to observe any of these behavior traits in other squirrels after being taken from its nest. This squirrel was fully grown by September.

Little is known regarding the longevity of this species. Ross (1930) called attention to two that were kept as captives for 11 years. This pair had a male offspring that was 8 years old. Whether they ever attain these ages in nature is not known.

Home Range and Territory

The daily activity of the eight marked squirrels, three males and five females, on the 6.31 acre area previously described was observed (March and April, 1945) to ascertain the shape and size of home ranges and territories (Figs. 41 and 42). Although nearly all of the 2400 acres in Bidwell Park is still under natural conditions, this particular area was not. On it were growing such introduced plants as almonds, Monterey cypresses, elms, and silver maples, all of which greatly increased the food supply and nesting sites over that provided by the native Digger pines, valley oaks, black walnuts, alders, cottonwoods, and sycamores. As many as 11 adult squirrels were seen on this area although part of the home ranges of a few were just outside of it. Four litters were known to be raised on the area at this time, and another pregnant female established her home range there before the following May.

Male squirrels are apparently much more compatible than are the females. The three marked males were frequently seen feeding within a few feet of each other on the ground or in the trees.

Home ranges of females varied from .30 to .85 acres, and as a result, there was considerably less overlapping than was the case with the home ranges of the males which varied from 1.15 to 1.53 acres each (Figs. 45, 46, 47).

Three territories defended against other squirrels were studied at a time when the females were nursing young. Only two of these were entirely within the area, however, and are shown in the diagrams in relation to the home ranges (Fig. 47). Territories of these two lactating females were one-fourth to one-third the size of their respective home ranges. All squirrels regardless of sex were chased from the territory whenever they were seen by the female that occupied it. When she was in her nest other squirrels sometimes would cautiously enter and take food from the trees. How long the territory was defended after the young squirrels left the nest was not determined.

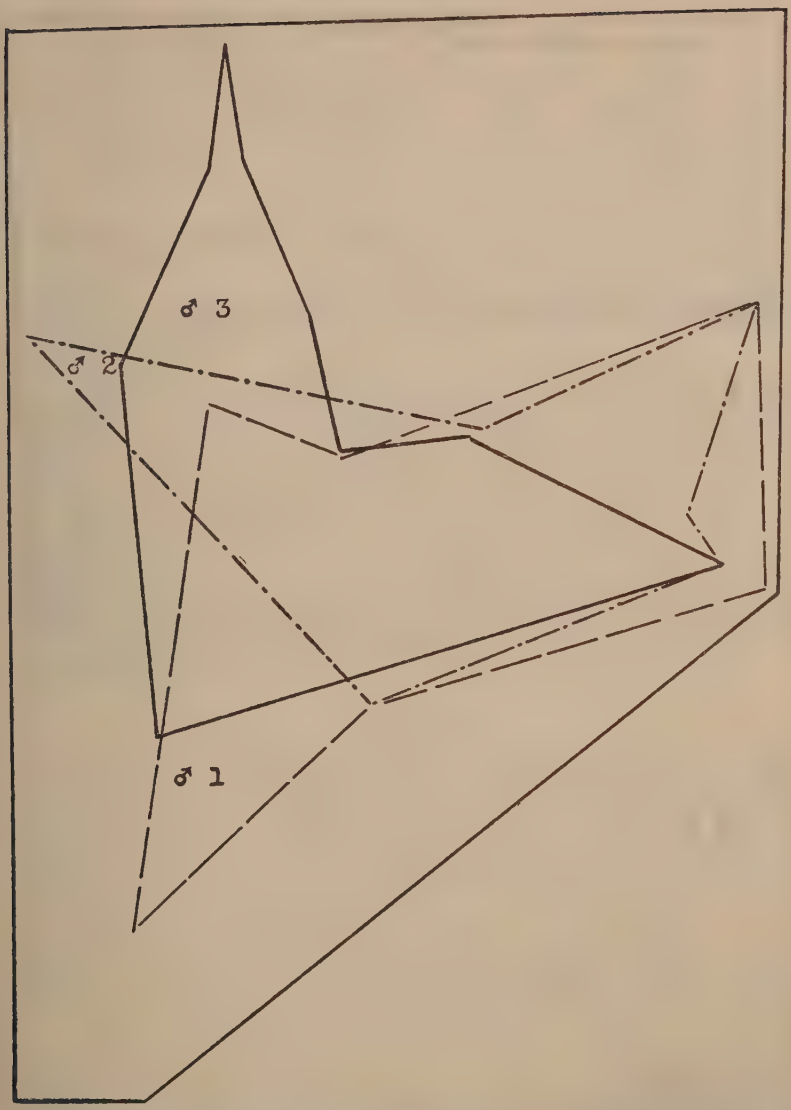

FIGURE 45. The home ranges of three marked male California gray squirrels on a 6.31 acre tract in the Sacramento Valley during March and April, 1945. Scale .25 mm. equals one foot.

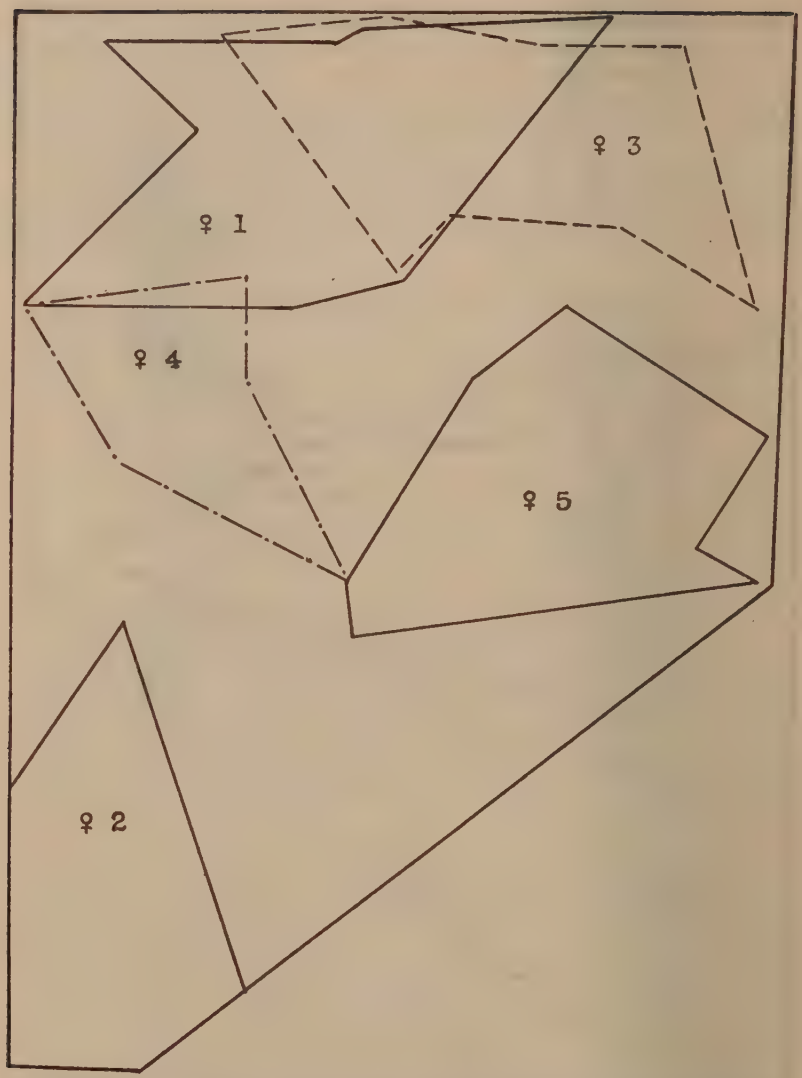

FIGURE 46. The home ranges of five marked female California gray squirrels occupying at the same time the same area as shown in Figure 45. Three other unmarked animals of undetermined sex also occupied this area during this time.

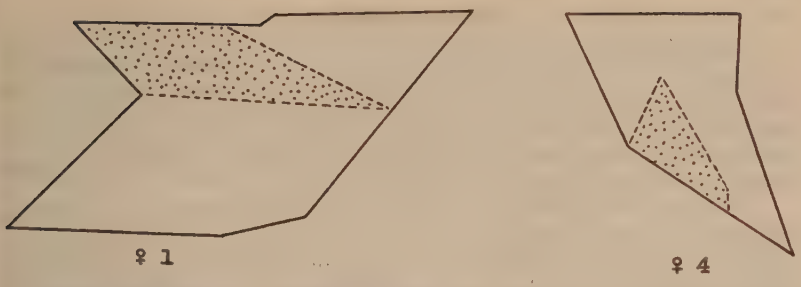

FIGURE 47. The home ranges and territories (stippled) of two marked female California gray squirrels in the Sacramento Valley during March and April, 1945. Scale .25 mm. equals one foot.

There was considerable daily movement of squirrels between nesting and loafing places, and feeding places. This was particularly noticeable between the riparian habitat, which provided excellent nesting and resting sites, but little food, and the pure oak stand habitat which had plenty of food but little else. Squirrels could be found feeding in the oak habitat fully 200 yards from the stream (or other water) at nearly any time of the day, but when surprised they would invariably climb a tree and take an arboreal route back to a hole or dray in the sycamores and cottonwoods by the stream. The animals seemed to sense their greater security in the riparian habitat and were more likely to be seen there. Six round trips through both these habitats revealed 24 squirrels, 18 of which were in the riparian and six in the oak habitat.

Populations

The populations of gray squirrels in California have been variously estimated. Grinnell and Storer (1924) believed there was only about one squirrel on each 10 acres of native range in the foothills. They estimated the squirrel population in the Yosemite Valley to be about one squirrel on each acre. Stanley (1916) reported gray squirrels to be common enough in the Plumas National Forest to enable one to see 30 to 40 a day.

During March and April, 1945, on the 6.31 acre area that was intensively studied in Bidwell Park, there were 11 adult squirrels. At this time four of these were known to be lactating and another was pregnant.

As was previously pointed out, this area contained several nonnative trees that doubtless supplemented materially the food and nest sites provided by the native trees and enabled this area to support a larger number of squirrels than it would in a truly native state. There was at no time insufficient squirrel food, but there was much evidence of competition for nesting holes. On this small protected area predators play a negligible part, the population being kept down by accident on a nearby road and possibly by diseases which might account for the occasional reduction in numbers from 75 to 100 percent, such a reduction having been pointed out by Peterson (*op. cit.*).

Economic Status

Near Paradise, Butte County, a nut grower reported the killing of hundreds of gray squirrels over a period of 10 years because of the damage they did to his English walnut grove. This grove borders a yellow pine-white fir woods where squirrels are very numerous. Almond trees that grow on small lots in the suburbs of Chico are rarely harvested because of squirrels and acorn woodpeckers.

The flesh of the California gray squirrel is delectable, and the animal was formerly considered as game with an open and closed season. It was first given a closed season in California in 1901, when the open season extended from August 1st to February 1st. In 1905 there was no open season, and in 1907 the season extended from September 1st to January 1st, and the bag limit was 12. In 1923 the animal was taken from the game list because of a serious reduction in its numbers and it has been given protection ever since, until 1946 when the season was again opened.

Suggestions for Habitat Improvement

The habitat of the gray squirrel can be improved in places where more squirrels are desired, by planting certain trees. Western sycamore and Fremont cottonwood provide more holes for nests than any other trees in the lower Sonoran life zone. In the upper Sonoran life zone, blue oak, and in the transition life zone black oak provide best nesting sites and best food trees. Trees which may be introduced to supplement the local native food supply are silver maple, black walnut, mulberry, and Monterey cypress. Digger pines and yellow pines are the most important native conifers in the upper Sonoran and the transition zones respectively. The frequency with which the animals are found in the vicinity of abandoned and even occupied foothill ranches attests their adaptableness to man-made environments, especially to the food on the ornamental and nut trees. Walnut trees grown from seeds planted along the foothill streams throughout California would greatly increase the food of these animals and might be the decisive factor in maintaining sufficient breeding population in years when the acorn or the digger pine cone crop fails or is greatly reduced. A few nut-bearing walnut trees close to a stream will, after a few years, establish young trees in favorable places for miles below the original parent trees.

Summary

1. A study was made of the ecology and life history of the California gray squirrel in some limited areas of California between 1940 and 1946. Two areas in the valley oak association in the Sacramento Valley were selected for daily observations on some marked animals during March and April, 1945.

2. The daily activity and response to weather conditions was found to differ from that described for the eastern gray squirrel. The animals were more active in the morning than at midday or late afternoon. Activity before sunup and after sundown was rarely observed. The kind of weather had little effect on activity.

3. The sense of smell seemed to be fairly well developed and used to locate food buried in the ground. The sense of sight likewise appeared to be well developed.

4. Gray squirrels are important and beneficial animals in reforestation in the valley oak association not adjacent to agricultural areas.

5. The most important competitors are the acorn woodpecker, Beechey ground squirrel, and the Douglas chickaree. Very few predators are known. Many squirrels are killed on highways by cars.

6. Four species of fleas are known to parasitize these squirrels. Devastating diseases apparently sometimes entirely eliminate or greatly reduce the numbers of gray squirrels over large areas. One of these is caused by a scabies mite.

7. The fruits of a large number of native and introduced plants are used for food. Flower buds and leaves of chickweed are frequently eaten by lactating females. The squirrels were rarely seen to use animal food.

8. The rut may occur any time during the first six months of the year. Each female appears to have but one litter of two to four young each year. The gestation period is probably over 43 days. Two kinds of nests are built.

9. A captive young squirrel exhibited a sequence of inherited behavior patterns as it grew older.

10. The home ranges of the males varied from 1.15 to 1.53 acres each. These overlap greatly the ranges of other squirrels. Males are generally compatible. The home range of individual females varied from .30 to .85 acres. Females were generally incompatible during the breeding months. The territories of lactating females were about one-quarter to one-third the area of the respective home ranges.

11. The population varies with the type and amount of plant cover. The greatest concentration noted was 11 adults living on a 6.31 acre tract in the Sacramento Valley. By means of habitat improvement the populations in most areas might be increased by planting certain introduced trees to supplement the food during the non-producing period of the native trees.

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ECOLOGY OF A COTTONTAIL RABBIT (SYLVILAGUS AUDUBONI) POPULATION IN CENTRAL CALIFORNIA

By Henry S. Fitch
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The cottontail rabbit of the western Sierra Nevada foothills *(Sylvilagus auduboni vallicola)* is sufficiently abundant in some areas to figure in the ecology and economy of the region in various ways—as a game animal as a reservoir of disease potentially transmissible to humans; and as a destroyer of vegetation, either cultivated crops or forage on range lands. During the course of wildlife studies at the San Joaquin Experimental Range, data were collected bearing on various phases of cottontail ecology. Especially during 1939, 1940, and 1941, many rabbits were live-trapped incidental to the trapping of ground squirrels, and information was obtained as to their numbers and activities, and various other factors, on an 80-acre area.

The experimental range is situated in, and typical of, a foothill belt used primarily for grazing of beef cattle. Interest in the rabbits in this region centers in their effect on range forage. The species is little hunted in this part of the State, partly because other more popular small game species are abundant, partly because it is heavily infested with fleas, and partly because it is considered unsafe to handle since it is a carrier of tularemia. This region is mainly open woodland of oak *(Quercus douglasii* and *Quercus wislizenii)* and pine *(Pinus sabiniana)*, occasional patches of chaparral and an annual type forage of broadleaf herbs and grasses; mostly it is rolling land, but there are occasional bluffs and ravines. The soil is generally shallow and rocky; outcrops and loose piles of decomposing granite rock are prominent features of the terrain. The brush patches and rock piles provide shelter for numerous wildlife species including the cottontail. The climate is one of mild winters and hot, rainless summers with temperatures over 100 degrees F. Annual precipitation averages approximately 22 inches.

This study was part of a program of wildlife investigation planned and initiated by Everett E. Horn of the U. S. Fish and Wildlife Service, in collaboration with the California Forest and Range Experiment Station, U. S. Forest Service. Lowell Adams, Freeman Swenson, Frank Hagarty and Bernard Mitchell helped with the live-trapping. Howard Twining, Daniel F. Tillotson and John E. Chattin analyzed scats and pellets in connection with the predation phase of the work. Assistance rendered by WPA Project No. 165-2-08-225 is acknowledged.

Methods

The rabbit population was intensively studied on an 80-acre area by marking for future identification and releasing all that could be live trapped. At each capture, sex, weight, catalogue number or formula, and exact location of the animal were recorded in the field. Those taken in 1939 and 1940 were marked with serially numbered aluminum ear tags

and colored celluloid disks manufactured for use by commercial rabbit breeders; those trapped in 1941 were marked by toe clipping. Food habits data were obtained on this same area by following rabbits as closely as possible recording the kind and amount of vegetation taken.

Seasonal Bait Acceptance

During 1939, 1940 and 1941, trapping effort was fairly constant year-round; on the 80 acres where population studies were made, approximately 200 traps were kept set for several days each week. Differences in the catch of rabbits reflected both actual changes in their number and changing seasonal acceptance of the grain baits used. Throughout the growing season, October through May, while green food was abundantly available, rabbits only rarely entered the traps. It is assumed that natural foods were much preferred to the grain mixture of wheat and milo maize with which the traps were baited. In summer after the main forage crop had dried out, grain was taken freely, and nearly all recorded captures of rabbits were in the dry season—summer and early fall. The total number of captures recorded each month during the three-year period in which live trapping was in progress is shown in Fig. 48. Each year the catch was highest in August at the peak of the dry season. Trends were similar for all three years, but in 1939 bait was taken much more readily. During the dry season that year natural food was scarce due to the short forage crop and early drying. In 1941 the forage crop was heavier and succulence longer persisting than in 1940, and the catch of rabbits was correspondingly light. During the course of live trapping,

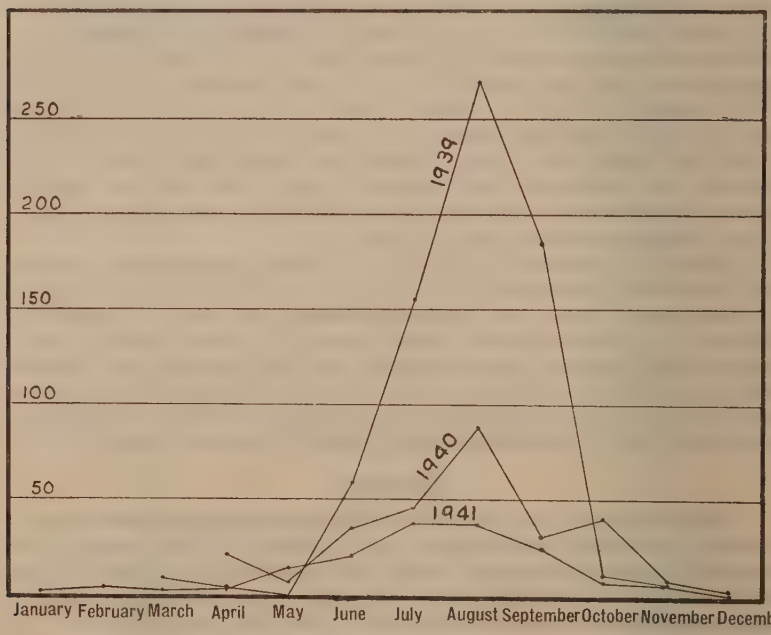

FIGURE 48. Numbers of captures of cottontails from month to month on 80-acre trapping area in three different years. Trapping effort was fairly constant through the year and the fluctuating catch reflects seasonal variation in bait acceptance.

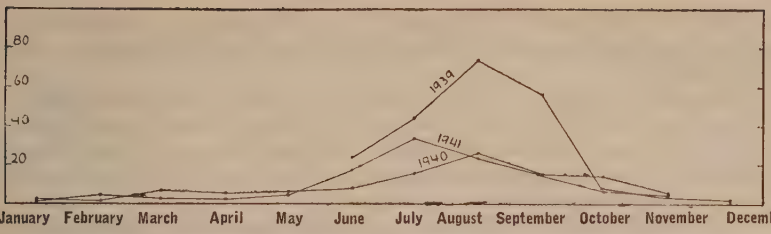

FIGURE 49. Numbers of cottontails live-trapped on an 80-acre study area each month in 1939, 1940 and 1941. The month-to-month changes in total catch are influenced mainly by changing bait acceptance rather than by actual changes in numbers of rabbits.

the few rabbits caught in winter and spring were often individuals which had been trapped frequently during the preceding dry season, and had perhaps acquired a special liking for the bait used.

Movements

During the three-year period, 228 rabbits were trapped a total of 1,159 times. The different locations of capture for an individual provided information concerning extent of foraging range, homing propensities, and shifts in centers of activities.

Foraging Range. Numerous captures of some individuals within a fairly short time revealed the extent of normal foraging activities or "cruising radius." As the numbers of records on individual rabbits increased, the foraging ranges plotted from them usually tended toward an oval shape. In many instances diameters of foraging ranges may be indicated by the maximum distance recorded between points of captures. When records are few, the distance is apt to be unrepresentatively short. For the 134 individuals each trapped at different locations on the area, maximum distances between points of capture, "foraging diameters," are presented in Table 1.

TABLE 1

	2 captures	*3 to 5 captures*	*6 to 11 captures*	*11 to 21 captures*	*21 or more captures*
Number of rabbits	27	36	39	27	5
Average of foraging diameters in feet	451	496	723	781	1044
Extremes of foraging diameters in feet	30-1,450	50-1,200	250-2,100	250-1,700	820-1,300

If the sexes differ in extent of home range, the difference is slight. Females may move about somewhat less than males, but some of the largest home ranges, plotted for individuals having many repeat records, were those of females. The average "foraging diameter" for all females (72) captured at more than one point was 626 feet, as against 632 feet for the entire group of 134, including both sexes. If the distances between captures actually represent the extent of foraging areas, home ranges of, roughly, eight or nine acres for both sexes were indicated, but probably in most instances the areas were somewhat larger. Ingles (1941: 234) wrote of this same species studied at a locality 200 miles northwest: "The home range of a male rabbit may be as much as 15 acres since three

were taken at stations 400 yards apart. The home range of a female rabbit is often less than an acre, which may be shared with as many as four other rabbits."

The difference may be due to the spotty distribution of food and of shelter—scattered clumps of blackberry thickets—where Ingles' study was made. His conclusions were based on comparatively few individuals on a small area. The open and uniform terrain on the Experimental Range would promote extensive movement.

Measured distances between points of capture are not entirely satisfactory for showing home ranges. The shorter distances represent indi-

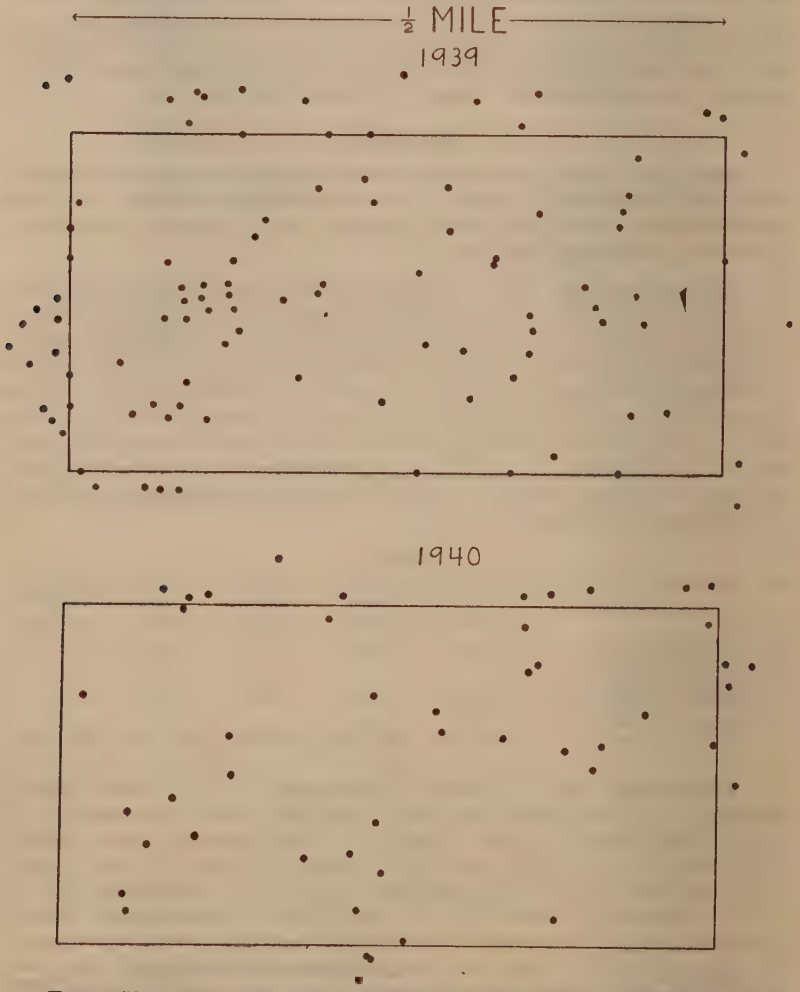

FIGURE 50. Map showing distribution of individual cottontails live-trapped in 80-acre study area in summers of 1939, 1940. Each dot represents central point of an individual home range. Note relative abundance in 1939, and concentration near left margin of area where water was available.

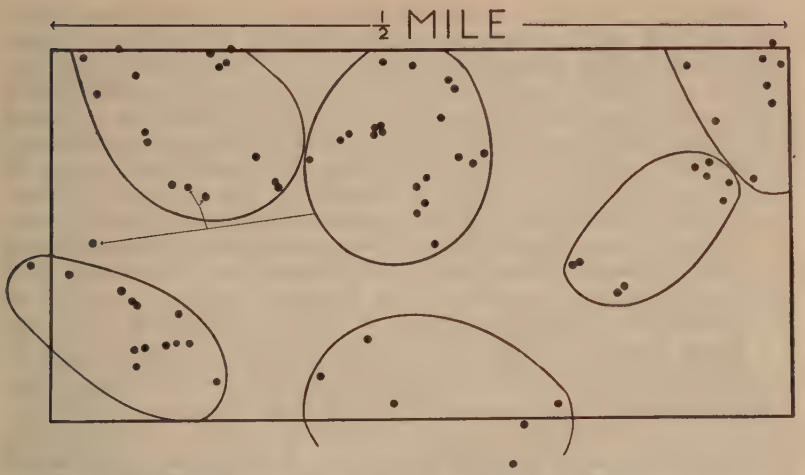

FIGURE 51. Home ranges of six different cottontails on 80-acre study area, as plotted for each from points of capture over periods of months. Three outlying points of capture from home range in upper center evidently resulted from trips to water supply outside usual range.

viduals for which the records do not reveal the true extent of the areas covered while the longer distances in some instances may represent unusually long foraging trips, and in others possibly reflect shifts of headquarters over periods of time. The median of "foraging diameters" recorded, for all those with more than five captures, was 700 feet. This distance is probably roughly representative of the diameter within which most of the activities of an individual are confined.

Several opportunities arose to watch the extent of movements of unusually tame and easily recognizable individuals frequently encountered in the field. Two in particular were intensively observed and were often followed in attempts to record their feeding. One of these was an old female, the other was a young of the year slightly more than half-grown. Both were somewhat more limited in their observed movements than were other individuals whose ranges were revealed by trapping, but the observations were made principally around dusk. Though activity is pronounced at that time of day, it appears that the rabbits then tend to forage in proximity of cover, ranging more widely after dark. Individuals were often trapped at night in areas of open grassland where they were never seen to venture in the daylight, and droppings were also abundant in such places.

Small young have much smaller foraging areas than have adults. One was usually seen foraging within a few yards of some pile of rock or brush or similar shelter into which it might dash at any alarm. Young less than half-grown were trapped in small numbers; usually a larger size is reached by the time the dry season sets in rendering grain bait more attractive than natural foods. A few young did seem to acquire a taste for the bait early in the season, and these entered traps frequently, each always at about the same place near the edge of some covert. The rabbits moved a good deal more widely than the ground squirrels which were trapped on the same area.

Homing. Ability to return within a short time to the home range with which it was familiar was demonstrated by each of three rabbits which made homing movements of 4,400 feet, 3,550 feet, and 3,150 feet respectively, after being trapped and removed from the experimental range headquarters where cottontails were often troublesome in taking bait set out to trap quail. Twenty others similarly trapped and removed to the rabbit study area slightly more than three-fourths mile away, all failed to make homing movements, apparently. Ten were never recaptured, and the remaining 10 were recaptured on the study area; several of them were taken repeatedly over long periods of months indicating that they had settled down in the new location near where they were released. Distances of movement from the point of release recorded for members of this group after recapture varied from zero to 2,200 feet.

Shifts of Range. Only one clear-cut instance of shift in range, or migration was obtained. This involved a male trapped five times within a two-weeks period in August, 1940, when it was less than half-grown. All these records were within an area of 450 feet diameter. The remaining record for this animal was obtained on June 2, 1941, when it was killed near the headquarters area, having made a movement of 3,300 feet.

The study area was not well adapted for the recording of long movements since it was only a little wider than the maximum diameter of a foraging area, and but twice as long. Shifts of range in most cases would have taken the rabbits beyond its boundaries where they would not have been recorded except by accident.

However, such shifts may be an important factor in affecting the population turnover which is apparent from the trapping records. Many rabbits were caught frequently over periods of weeks and then disappeared abruptly from the records even during the dry season when bait acceptance was still good. Perhaps most of these were actually eliminated by predators and other causes of natural death, but some possibly transferred their activities elsewhere.

During the dry season of 1939, forage in general, and especially succulence and water, was unusually scarce. Near one end of the study area, seepage in the dry creek bed, and a nearby stock trough, furnished watering places much used by the rabbits. Trapping records that year indicated some clustering in this part of the area, while the 1940 records were more evenly distributed.

Further evidence of shift in foraging range to include critically needed food or succulence was obtained at the headquarters area. Here, two unfenced lawns were watered regularly through the summer. These lawns were within a cleared area adjacent to roads, buildings, and a small orchard, where rabbits were rarely seen during the green season. But in the dry season, especially in 1939, the lawns were exceedingly attractive to the cottontails. Shortly before dusk they would begin to congregate, and later in the evening a person driving up in a car would often see as many as 30 dashing from the lawns to seek cover. It seemed evident that most of the individuals involved had extended or actually transferred their foraging ranges to include the area of the lawns.

Population

On the 80-acre area where live-trapping was carried on, information was obtained regarding the population density of cottontails. In computing the numbers actually present, use was made of the Lincoln Index—the ratio obtained in a given sampling period, of previously marked individuals recaptured to all those caught, including some not previously marked. The census formula used was as follows:

$$\frac{\text{Total population of 80 acres}}{\text{Number caught January to July}} = \frac{\text{Number caught August to December}}{\text{Number caught January to July and recaptured August to December}}$$

In choosing the two sampling periods necessary for the computation, most plausible figures were obtained by division into a January to July preliminary period during which part of the population was trapped and recorded, and an August to December post-census sampling to obtain the ratio of the previously marked individuals to the population as a whole. This division of periods was made to include, in each, a part of the July-August season of maximum bait acceptance. Other divisions in which one or both periods fell within a spring or fall season of poor bait acceptance and few captures produced obviously distorted census figures. The numbers trapped which were used in the census, were as follows:

Year	*January to July*	*August to December*	*Both Periods*
1939	49	78	25
1940	22	31	13
1941	49	35	18

From these figures, census computations were made as follows:

1939 census

$$\frac{x}{49} = \frac{78}{25} \qquad 25x = 3722 \qquad x = 153 \text{ cottontail}$$

1940 census

$$\frac{x}{22} = \frac{31}{13} \qquad 13x = 682 \qquad x = 53 \text{ cottontail}$$

1941 census

$$\frac{x}{49} = \frac{35}{18} \qquad 18x = 1766 \qquad x = 95 \text{ cottontail}$$

In each instance the figure obtained represents the number present in early summer—a population of adults, and subadults or well-grown young of the year. Aside from the pronounced year-to-year fluctuations suggested by the above figures, the population, of course, goes through an annual cycle resulting from the seasonal limitation of breeding, but the pattern of this cycle cannot be shown with present data. The population presumably undergoes rather gradual reduction throughout the dry season, until it is again augmented by the annual crop of young, perhaps several litters for each female during the course of the breeding season. Most of these small young are rapidly eliminated during the time they are helpless in the nest and for many weeks afterward while they are extremely vulnerable to predation.

The annual Lincoln Index census probably gives a fairly accurate approximation of the numbers present on the area. Checks were obtained by the use of one-month sampling periods. From these censuses the following figures were obtained for July and August for each of the three years.

	1939	*1940*	*1941*
July	153	39	76
August	152	36	38

These are considered less accurate than the figures from the six-month sampling periods, mainly because of the smaller numbers involved. The August 1941 figures are considered particularly unreliable since they were dependent upon the small and inadequate sampling in September of that year when bait acceptance was poor.

Even assuming that the actual census figures obtained are an accurate representation of the numbers on the area, they do not indicate correctly the population density, for many of the animals trapped on the area ranged outside it in varying degrees, some perhaps merely overlapping its boundaries in the course of their wanderings. By plotting the range of each individual rabbit, on the basis of distribution of its sites of capture, attempt was made to determine what percentage of its range lay outside the study area. Those having numerous records all well inside the boundaries were assumed to forage entirely within the area. Those whose records of capture clustered along one edge were assumed to range mainly outside, the estimated percentage depending on the pattern of the location records and the known extent of typical foraging ranges in other individuals. Those for which only a single record was available near an edge, were assumed to range almost entirely outside the area. In a few instances where only one or two location records were available, the estimate was merely a guess but usually the range was roughly evident. In several samplings by live-trapping of a peripheral strip, many of the marked rabbits were recaptured and the extent and direction of their activities outside the main study area were indicated. Attempt was made to estimate to the nearest 10 percent the portion of each range falling within the trapping area, but at best these estimates are merely approximations.

For 103 rabbits trapped on the area in 1939, the sum of percentages of ranges on the area totaled 6,575; dividing by 100, there were the equivalent of nearly 66 complete "rabbit ranges" within the 80-acre area. This indicates a population density of one cottontail to 1.2 acres. For the 47 trapped in 1940 percentages of ranges totaled 3,000, representing 30 "rabbit ranges" or a population density of one per 2.6 acres. Using the data in a different manner, it appears that of the 103 present in 1939, 55 had ranges centering inside the area, 35 centered outside, and 13 centered in the immediate vicinity of the boundary, or yielded such meager data that it could not be determined on which side they centered. In 1940 comparable handling of data indicated that 32 centered inside and 15 outside the area.

It is evident that, in the vicinity of the trapping area at least, the 1939 summer population had undergone sharp reduction by the summer of 1940, but with no apparent cause. In a preliminary paper on ecology of wildlife species of the San Joaquin Experimental Range (Horn and Fitch, 1942:115) it was stated concerning the cottontail population: "***during 1939 and early 1940 their numbers remained fairly stable

except for seasonal fluctuations. During the summer of 1940 the numbers dropped to less than half of the 1939 summer populations, most of this reduction occurring over a six-weeks' period." Further study of the data suggests another interpretation. No dead or diseased rabbits were seen during the time of the supposed reduction which was based mainly on impression. But it does appear that the reduction must have involved unusually heavy mortality of adults rather than mere variation in the success of the annual crop of young. Thus of the 103 rabbits caught on the area in 1939, only 9, or 8.7 percent were recaptured in 1940. But of the 47 total caught there in 1940, 18, or 38 percent were recaptured in the 1941 season. Survival expectancy of adults was more than four times as high in the summer of 1940—other things being equal. Possibly during the critically dry conditions of 1939, the animals moved about so much more extensively that this, rather than actual mortality, was an important cause of population turnover on the 80 acres.

In the early summer of 1940 an attempt was made to determine the population density of the rabbits over the range as a whole. Road counts were made, driving in a car at 10 miles per hour after dark in the early part of the night at times apparently favorable for rabbit activity. The roads followed passed through 12 different experimental pastures totaling 1,754 acres in area. For each road count made on these various pastures a comparable road count was made on the 80-acre study area where the population was evident through live-trapping data. Thus the relative abundance could be judged from the numbers seen per unit of time on any area as compared with the trapping area.

On the 80-acre trapping area, in 739 minutes of driving, there were seen 41 rabbits, or an average of one in 19.8 minutes. In 1,023 minutes of driving on roads of the other pastures, 88 were recorded—an average of one in 11.7 minutes. Thus rabbits were apparently 1.7 times as abundant on the larger area. The population of the trapping area was computed at one to 2.6 acres, or .384 per acre. Thus the population density of the 1,754 acres would amount to 1.7 x .384, or .654 rabbits per acre. This is the only available computation of the cottontail population over the experimental range as a whole, but it represents a low point in both the year-to-year fluctuations and the annual cycle. Thus, at times it may amount to several per acre, especially in areas that are unusually favorable as cottontail habitat.

The 80-acre study area appeared to be one of the less favorable places on the Experimental Range for cottontails, as it bordered, and partly included, rolling grassland where cover was relatively scant. On other areas of the Experimental Range more rugged terrain with abundant granite rock piles, patches of chaparral, and fallen live-oaks with their dense protective screen of twigs, provided optimum cottontail habitat.

Feeding

The feeding of cottontails on the Experimental Range is determined by the changing seasonal availability of food plants. In this region the food consists almost entirely of annual grasses and broadleaf herbs. In late fall, winter, and early spring (the growing season) many species were suitable for food, providing succulence and high protein and mineral content. In the summer dry season feeding conditions were much less favorable; protein and mineral content of the forage crop in general

had dwindled, crude fiber had increased, and only a few species retained succulence. This remaining succulence was concentrated in the larger swales, and creek beds, but in years that are more than ordinarily dry it may be largely lacking. Presence of water then becomes a critical factor.

Seasonal trends in the feeding habits are best illustrated by extracts from field notes concerning feeding behavior recorded on different dates.

In late March feeding rabbits were observed to take tips of grass blades, foxtail fescue (*Festuca megalura*) and soft chess (*Bromus mollis*), stems of popcorn flower (*Plagiobothrys nothofulvus*), and fruits of filaree (*Erodium botrys*). Throughout April the flowering heads of an abundant small composite, gold fields (*Baeria chrysostoma*) were an important food. Popcorn flower stems and soft chess heads and once a plant of everlasting (*Filago gallica*) were also observed eaten in April. A rabbit eating heads of soft chess was seen to reject those of red brome (*Bromus rubens*) after reaching up to sniff them.

In June dry heads of soft chess were an important food perhaps because of ready availability. One rabbit watched for 58 minutes took 244 heads of soft chess and nothing else. Slender-leaf rush *(Juncus oxymeris)*, heads of foxtail fescue, plants of Spanish clover *(Lotus americanus)*, stalks of tarweed *(Hemizonia virgata)*, leaves and seed heads of Australian chess *(Bromus arenarius)*, and heads of clover *(Trifolium* sp.) were taken in quantity; oat *(Avena barbata)* and leaves and bark of buttonwillow *(Cephalanthus occidentalis)* were also seen eaten on one or more occasions.

In July several observations indicated that stalks and heads of soft chess continued to be the principal foods. Stalks and heads of fescue, lupine *(Lupinus formosus)*, tarweed, turkey mullein leaves *(Eremocarpus setigerus)*, dock *(Rumex* sp.) and, on one occasion, dry oak leaves were seen taken. The turkey mullein, dock, and tarweed were apparently used because of their succulence at this season when most other vegetation was dry.

In August tarweed was increasingly used. In one rabbit followed throughout a foraging period, tarweed was estimated to comprise 90 percent of the meal. In feeding on tarweed the animal usually cut the stalk and ate outward from its base, discarding the terminal parts. Soft chess heads and straws continued to be important foods. Several times rabbits were observed grazing on the surface mat of cast seeds of foxtail fescue. Rushes *(Eleocharis* and *Juncus)* already too closely cropped to be accessible to stock, continued to provide an important source of food and succulence to the rabbits. Spanish clover, turkey mullein, dock and thistle *(Cirsium* sp.) also were recorded as being eaten in August.

In September rabbit grazing on cast fescue seeds was recorded several times; also use of soft chess, toad rush, flowers of tarweed, and dry navarettia *(Navarettia* sp.)

The only October feeding record obtained was of a cottontail taking a dry turkey mullein plant.

The quantities of forage required to maintain a cottontail are not well known. In a summer feeding experiment, a 340-gram young fed for 25 days on dry wheat, with water available, ate on the average 14.5 grams daily—only 4.1 percent of its body weight. A 950-gram adult in 11 days of feeding ate an average of 23.7 grams daily—only 2.5 percent

of its body weight. However, both rabbits lost some weight during the experiment, and this concentrated food is unrepresentative of their diet in the wild. Ingles (1941:239) records that two adults which he fed a mixture of green forage for a 15-hour period ate 209 grams and 171 grams, respectively. In estimating rabbit damage on the range, allowance must be made for the fact that plants cut and destroyed are often only partly eaten, that vegetation is adversely affected by trampling, on the runways and elsewhere, and that plants eaten back in the early stages of growth are stunted. The total damage therefore greatly exceeds the loss of vegetation actually consumed by the rabbits.

Weights

Weight was recorded at each capture, and was found to fluctuate widely. Adults usually weighed between 750 and 1,300 grams; those in good condition frequently weighed more than 1,000 grams. Day to day fluctuations of 40 grams or more were often recorded, apparently due

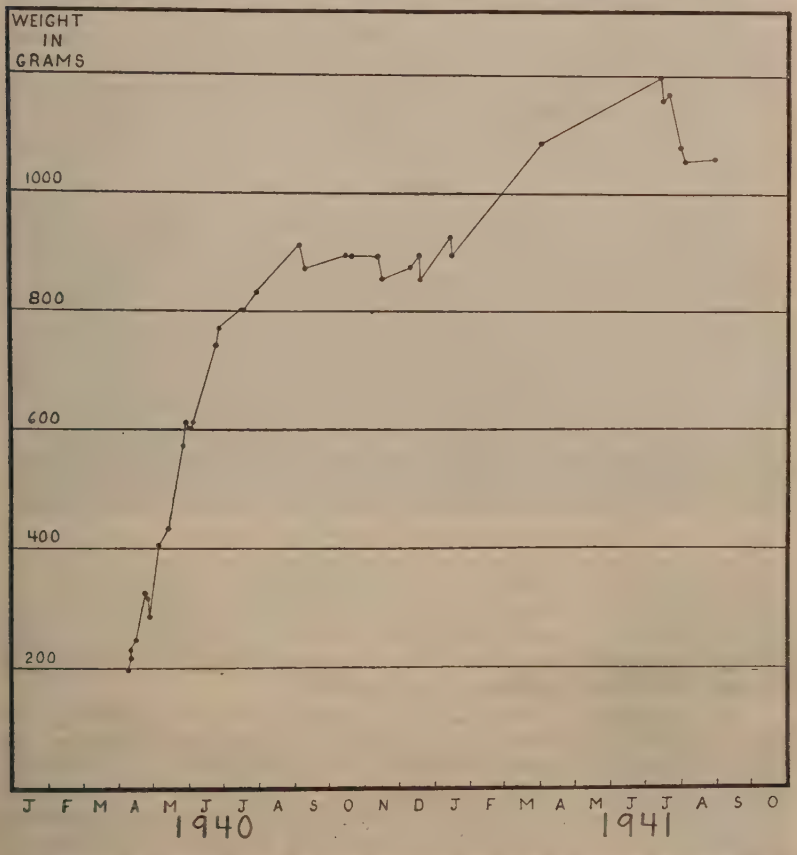

FIGURE 52. Weights of a female cottontail on dates of capture beginning soon after leaving nest, showing rapid gain for first three months with more gradual and less regular subsequent growth.

mainly to differences in extent of feeding before capture. Individuals caught frequently over periods of weeks often tended to lose weight, possibly as a result of facial bruises sustained in their attempts to escape, which perhaps made eating difficult and painful. Seasonal trends in weights are somewhat obscured by this tendency to weight loss in consistent repeaters.

In late summer of 1939 there was a general downward trend in weights evidently resulting from the short forage crop with lack or early disappearance of swale succulence during the dry season. No such tendency at this time of year was apparent in 1940. Maximum weights were recorded in April and May, but few were caught at that season, as bait acceptance was poor.

For an adult female caught 21 times in nine different months over an 18-month period, average monthly weights were as follows: August, 1939—1,052 grams; September, 1939,—1,012 grams; January, 1940—1,055 grams; April, 1940—1,225 grams; July, 1940—1,180 grams; August, 1940—1,110 grams; May, 1941—1,300 grams; August, 1941—1,055 grams; February, 1942—(dead in trap)—825 grams.

Unusually complete weight records were obtained for one female rabbit first trapped as a small juvenile soon after leaving its nest, and recaptured frequently during the ensuing 17 months, even during the winter season when bait acceptance was low. The weight records for this individual are shown in figure 52.

Reproduction

Breeding is ordinarily limited to the late fall, winter, and spring months—the growing season when green forage is abundant. In rabbits trapped during the dry season, the genitalia had retrogressed so that sex was not readily determined, and it was evident that breeding activity had ceased. The reproductive physiology may be controlled by the seasonal change in diet. As an exceptional instance, a one-third grown young was seen in November, 1946, in the headquarters area. It must have been born during the dry season, but the watered lawns and gardens around the headquarters buildings may have provided green feed necessary to stimulate reproduction at a season when it does not normally occur. Orr (1940:143) stated that "The breeding season of the Audubon cottontail in California extends from December to June." On the experimental range observations suggest that it may begin and end somewhat earlier. Concerning the rate of reproduction, Orr (loc. cit.) stated: "Sufficient data are lacking to definitely state the number of litters born annually, but considering the length of the breeding season it is not improbable that in many instances this number may exceed two. The average number of young per litter, based on records of 19 pregnant females, is 3.6 with extremes of two and six."

On November 9, 1940, an adult female was seen gathering dry grass for nesting material and carrying it to a burrow beneath an oak bush. After pulling up each mouthful, she would deposit it in the freshly dug burrow. Many mouthfuls of grass were gathered, all within three or four feet of the bush. This was probably near the beginning of the breeding season, and the nest evidently was being prepared for a litter of young.

On January 18, 1939, a nest was found on the surface of the ground in a rounded depression, well concealed by a dense covering of high grass. This was in a swale of an ungrazed area. The one young in the nest weighed 60 grams.

On the following day a destroyed nest was found where it had been dug out, in an exposed situation in sandy soil near a creek bed. The nest chamber was three inches below the soil surface, and the cavity was about eight inches long by five inches deep, with a bed of dry digger pine needles, a softer interior of dry fescue and rush, and a lining of rabbit fur. A fresh ground squirrel digging and feces were found about a foot from the nest suggesting the possibility that one of these rodents had robbed it.

FIGURE 53. Immature Audubon cottontail

On January 25, 1939, a nest with two small young rabbits was discovered. The nest cavity was just beneath the ground surface, and was lined with rabbit fur but had no plant material. The entrance and the cavity itself were so small that it would seem impossible for an adult cottontail to enter. The young still had their eyes closed, and had a sparse covering of hair.

On January 28, 1941, at about 10 a.m., another adult was seen making its nest. It was under a live-oak and was moving in a brisk, jerky fashion examining the ground litter minutely, and from time to time picking up dry oak leaves in its mouth. Having obtained a small mouthful of leaves, with a few straws and other debris mixed in, it entered a freshly dug hole with a mound of still moist earth in a more exposed situation on the other side of the tree. After a few seconds it backed out

having deposited its load, and resumed the search. In a period of about five minutes it made 15 trips into the hole with nesting material—mostly dry oak leaves and some dry grass (probably soft chess). At 4.30 p.m. the site was located with difficulty and it was observed that the hole was plugged with loose earth, and the burrow mound leveled and completely covered with a layer of dry oak leaves. Four weeks later this hole was dug out. The entrance was covered with dry oak leaves. The litter of young presumably had been destroyed early by heavy rains. The nest cavity, about a foot from the entrance, contained evidence of dead young rabbits.

Ordinarily the nests are so well concealed that they are rarely found while in use, but remains of those dug out and destroyed by predators were found frequently during the winter and spring months. Usually it was not possible to identify the predator involved. Only a few of those seen destroyed were recorded. On March 21, 1939, three such destroyed nests were recorded, and in the first week of May, 1938, several were noticed.

On April 10, 1939, a small young cottontail was seen in tall grass a few inches from the entrance of its nest burrow, into which it ran when disturbed. The burrow was dug out and was found to have a tunnel about eight inches long leading to a nest chamber five inches beneath the ground surface, which seemed barely large enough to contain an adult rabbit. It was lined with grass and a small amount of fur. Only the one young was found in it.

The nest recorded latest in the season was one discovered on May 24, 1938, when attention was attracted to it by a rattlesnake which was swallowing a very young rabbit and had three others already inside it. An adult cottontail was about 15 feet distant, and remained in the vicinity, allowing close approach. The nest was not dug out at the time of discovery but was investigated later in the day. At this time a second rattlesnake was found partly inside the nest, and it had eaten three more young cottontails evidently of the same litter. The entrance to the burrow was barely large enough to admit the snake's body, but it was partly plugged with loose dirt. The entrance led into a rounded chamber about 7 x 4 x 4 inches, with a nest of dry grass (soft chess and foxtail fescue) lined with rabbit fur.

From the foregoing accounts it is obvious that the habits of the cottontail in this locality are variable, as regards site selected for birth of litter, type of breeding burrow or lack of it, and composition of nest. Ingles (1941:24) has shown that the female cottontail may not even enter the breeding burrow but returns to it infrequently to allow the young to suckle as she stands over the entrance. In some of the nest burrows discovered this arrangement seemed unlikely because the nest chamber was several inches from the entrance. But other nests were so small that it was difficult to see how the adult could have squeezed inside. It is probable that squirrel burrows are sometimes used as breeding places by the cottontail. Extensive squirrel burrow systems may have as many as 100 open holes, many of which are not connected underground, and only a few of the entrances are regularly used by the squirrels in going to and from their nests. On winter mornings freshly dug mounds of earth heavily tracked by cottontail were often found beside such burrows,

showing that the rabbits had enlarged underground portions during the night.

Several times remains of cottontail too young to have left the nest were found partly eaten on ground squirrel burrow mounds, presumably victims of the squirrels. On one occasion a squirrel was seen carrying a live young cottontail in its mouth. Once a cottontail was seen chasing a squirrel around the edge of a bush, possibly in defense of its nest.

Natural Enemies

Several kinds of mammalian predators, at least four species of raptorial birds, and two of the larger species of snakes, all numerous on the experimental range and elsewhere in the general region, prey regularly upon cottontail. Many records of predation were gathered, and an attempt was made to compute the population density of each species which might be important as a rabbit predator. These data are not sufficiently complete to afford a clear picture of the role of predation in limiting the cottontail population, especially since the reproductive potential of the rabbits in this region is not well known. Some predator species take only the small young before these have left the nest. Other kinds take heavy toll from the adult population, but it is evident that the inexperienced young are especially susceptible to predation by many natural enemies. The combined toll of the several predators comprises an impressive total, which must be a major factor if not the decisive one in limiting cottontail distribution and abundance.

Coyote. Control of coyotes by trapping was begun on the experimental range in the winter of 1935-36. The recorded numbers eliminated each year from the 4600-acre area were as follows: 1935-36, 35; 1936-37, no record; 1937-38, "about 30"; 1938-39, "about 30"; 1939-40, 13; 1940-41, 13; 1942, 7; 1943, 5; 1944, 8; 1945, 1. Each year an unknown number was also eliminated from adjoining ranches. It is evident that in recent years the population has been held far below its former level. In 1939 and 1940, at the time the rabbit population was studied, the coyote population averaged perhaps one to 300 acres between the breeding season and the time of control operations the following winter.

In a year-round collection of 1,173 coyote scats, mostly from regular defecating places on roads and trails of the experimental range, in 1939 and 1940, 1,924 vertebrate prey items were identified. These made up most of the food, though supplemented by a few occurrences of grasses, berries, insects and some carrion. Of the 1924 items, "rabbit" (presumably cottontail, but possibly pertaining to the relatively rare jack rabbit in a few instances) made up 19.6 percent (21.1 percent in 1939, 17.0 percent in 1940). A truer interpretation of the relative importance of rabbit in the coyotes' diet here may be gained by computing its percentage weight of the total. The total live-weight of recorded items was estimated by obtaining the average weight for each species, multiplying this by the number of its occurrences, then adding up these totals. Cottontail, with an average of 800 grams, was the heaviest kind of prey recorded taken by coyotes in this locality. The weight used as standard for the cottontail, and those for other prey species represent in each case that of a small adult. Many or perhaps most of the prey animals taken by coyotes may have been immatures. The ratio of juveniles in various

stages to adult animals was perhaps roughly similar for each, but the usual adult weight affords the best standard of comparison.

Another variable is introduced by the inexact correspondence between number of scat occurrences and number of individual prey items eaten. But for squirrel- and rabbit-sized prey animals fairly close correspondence might be expected (Murie, 1946: 275). For mouse-sized rodents, and more minute items less accurate figures on the number eaten could be obtained, but this inaccuracy would not affect the proportions of the larger and more important items to any great extent. In general, the assumption of one prey animal of the average weight of the species for each scat occurrence, is thought to afford a rough approximation of the percentage by weight of the coyote's diet. The same assumption has been made for the other carnivores and raptors discussed below. In Table 2 prey weights by percentage were obtained from computations on this basis.

TABLE 2

Composition of Coyote Food
(Based on 1,173 scats)

Prey		*Occurrence in coyote food*	
Species	*Average weight in grams*	*Number of occurrences*	*Computed percentage by weight of total recorded prey*
Cottontail	800	377	45.4
Ground squirrel	500	414	31.2
Gopher snake	500	79	6.0
Woodrat	200	162	4.9
Pocket gopher	100	234	3.5
Kangaroo rat	60	361	3.3
Other (29 kinds)	variable	297	5.7
Totals		1924	100.0

It is indicated that by weight cottontail made up a greater percentage of the diet than did any other kind of prey, and amounted to nearly half of the total.

Gray Fox. At the time of the study, gray fox were probably somewhat more abundant than coyotes on the area, judging from trappers' estimates and the greater frequency with which they were seen. However, no basis for estimating their actual numbers is available. In June, 1938, a den was located with seven half-grown pups. Scattered remnants of prey in the vicinity included parts of several cottontail.

A small collection of 87 fox scats made on the experimental range contained 102 vertebrate prey items, besides a few insects, berries, and other plant material, and one occurrence of carrion. The scats were collected at different times of year but mainly represented the fall months.

The number of occurrences and computed percentages of the total prey weight for the principal prey species of the gray fox are presented in Table 3.

TABLE 3

Composition of Gray Fox Food
(Based on 87 scats)

Prey		*Occurrence in gray fox food*	
Species	*Average weight in grams*	*Number of occurrences*	*Computed percentage by weight of total recorded prey*
Cottontail	800	11	35.7
Ground squirrel	500	12	24.4
Woodrat	200	17	13.8
Bird (4 kinds)	variable	10	10.2
Pocket gopher	100	14	5.7
Kangaroo rat	60	17	4.1
Other	variable	21	6.1
Totals		102	100.0

Though this sample is too small to be relied upon, its trend seems to indicate that rabbit was the most important single prey species of the fox, and made up more than a third of the total.

Badger. Digging of badgers was frequently seen on the study area, but no basis for estimating the population of badgers was discovered. It is unlikely that these predators are able to catch adult cottontail except under unusual circumstances, but they may be responsible for much of the predation on small young in the nest. On many occasions cottontail nests dug out and destroyed by mammalian predators were found. Though the predator involved was never definitely identified, it is probable that badgers figured in at least some instances.

A badger kept in captivity throughout one summer consumed daily one small adult cottontail or its equivalent.

Bobcat. Judging from the occurence of their tracks, bobcats are fairly common in the more brushy and rocky parts of the Experimental Range, but nothing was learned concerning their actual numbers, or the food taken by them. As they are known to prey extensively upon rabbits elsewhere, (Grinnell, Dixon, and Linsdale, 1937:615, 618, 620) it is probable that they take large numbers of cottontail locally.

Red-tailed Hawk. This large raptor was determined to occur in a permanent population of about one to 160 acres, with an additional unstable population of fledged young and migratory adults, (Fitch, Swenson and Tillotson, 1946). Many instances of predation on cottontail were recorded. On one occasion the head of an ear-tagged adult male rabbit from the study area was found beneath the perch of a hawk about a quarter mile from where the rabbit had been trapped. On January 30, 1941, a hawk was seen to catch an adult cottontail by a sudden steep swoop from its perch on a 15-foot oak snag. The rabbit must have emerged from brush at the foot of the tree to cross an open space, completely unaware of the danger. It took this hawk about two minutes to kill the rabbit.

Among 625 prey items of the hawks recorded as brought to the young in the nests, cottontail were third in abundance with 62 records (all of young ones), and on the basis of weight were computed to comprise 26.5 percent of the total. Among 4,036 prey occurrences from 2,094 red-tailed hawk pellets, the more important kinds both in numbers and percentages of total weight are presented in Table 4.

TABLE 4

Composition of Red-tailed Hawk Food
(Based on 2,094 pellets)

Prey		*Occurrence in red-tailed hawk food*	
Species	*Average weight in grams*	*Number of occurrences*	*Computed percentage by weight of total recorded prey*
Ground squirrel	500	1,049	49.5
Cottontail	800	322	24.2
Gopher snake	500	190	8.9
Pocket gopher	10	794	7.4
Rattlesnake	300	70	2.1
Other	variable	1,611	7.9
Totals		4,036	100.0

Cottontail was third in abundance among all prey taken by the hawks, and comprised about one-fourth of the total prey weight taken.

Cooper Hawk. A few pair of these hawks nest on the experimental range, and in winter the population is considerably increased by migrants, but no definite figures on their numbers were obtained. In 1939, two nests were observed, and a total of 41 prey items were recorded, two of which were young cottontail (Fitch, Glading, and House, 1946: 153). The other prey items were all of smaller kinds, mainly birds and lizards, and the cottontail were estimated to comprise approximately 16 percent by weight of the recorded food.

In one instance an adult cottontail found freshly killed and partly eaten under the edge of a bush was thought to have been the victim of a Cooper hawk. These hawks are considered of secondary importance as cottontail predators because of their relatively low numbers, small size and preference for other kinds of prey.

Horned Owl. These large and common owls feed much more extensively on rabbits than on any other kind of food. Seven times, in the fall of 1938, spring and fall of 1939, and 1940, and late winter of 1941 and 1947, counts were made of horned owls heard at different points on a 1,920-acre section of the range. These counts representing the minimum number of owls present, varied from 15 to 25. Roughly, a population of one owl to a hundred acres is indicated. A sample of 654 pellets representing approximately 1,471 individual prey items was analyzed in 1939, 1940 and 1946. For the principal prey species, number of occurrences and computed percentages of total weights were as presented in Table 5.

TABLE 5

Composition of Horned Owl Food
(Based on 654 pellets)

Prey		Occurrence in horned owl food	
Species	*Average weight in grams*	*Number of occurrences*	*Computed percentage by weight of total recorded prey*
Cottontail	800	205	61.1
Woodrat	200	240	17.9
Kangaroo rat	60	201	4.5
Pocket gopher	100	115	4.3
Ground squirrel	500	13	2.4
Reptile (at least 8 kinds)	variable	44	5.0
Bird (at least 12 kinds)	variable	45	2.3
Other (including many insects)	variable	608	2.5
Totals		1,471	100.0

It is indicated that cottontail made up more than half the food by weight, though taken in slightly smaller numbers than woodrats.

Barn Owl. These are much less common than horned owls on the Range, and were seen at only a few places. In a collection of 240 pellets there were 517 prey items of which 415 were pocket gopher and pocket mouse. Only four were cottontail (all young) which were computed to make up around 3 percent of the total prey weight represented by the sample.

Rattlesnake. This reptile is probably the most common of all rodent and rabbit predators on the Range. Over a three-year period 679 were marked and released, and the ratio of these recaptured to others seemed to indicate a population of two or three per acre, but accurate census is impracticable as the figures might be distorted by many unknown variables. Of the rattlesnakes recorded, nearly half were adults. A total of 271 prey items were identified from stomachs and droppings of the snakes. For the principal prey species, number of occurrences and computed percentages of total weights see Table 6.

TABLE 6

Composition of Rattlesnake Food
(Based on 271 food items)

Kind of prey	*Average weight in grams*	*Number of occurrences*	*Percentage of total prey weight*
Ground squirrel	206	111	70.5
Cottontail	206	24	15.2
Kangaroo rat	60	32	5.9
Gopher	67	12	2.5
Other	variable	92	5.9
Totals		271	100.0

Though this food sample is small, as compared with those obtained for carnivores and raptors, prey weights were determined with a precision not practicable for the predatory mammals and birds. Food items were palped from snake stomachs, and were actually weighed, except those in which digestion had reached an advanced stage.

From these figures it appears that cottontail make up nearly one-sixth of the snakes' food. As a result of the winter and early spring breeding season most of the young were already too large for the snakes to eat when the latter emerged from hibernation. The peak of rattlesnake activity occurs during April, May and early June and all the records of predation of rabbits occurred during that time, involving late litters of young rabbits in the nest and large adult snakes in every instance. Squirrels and kangaroo rats were often found dead, showing evidence of rattlesnake bite, but some of the snakes involved were known to have been too small to eat the animals they had killed. Some rabbit mortality may occur also. On June 28th, an adult rattlesnake was seen to strike a cottontail in the field. Rabbits are probably less liable to be killed in this way than are burrowing rodents which often encounter the snakes underground.

Gopher Snake. This species is much less common than the rattlesnake locally—perhaps only one-fourth as numerous. A total of 70 food items were palped from gopher snake stomachs; and an analysis of these is presented in table 7.

TABLE 7

Composition of Gopher Snake Food
(Based on 70 food items)

Kind of prey	*Average weight in grams*	*Number of occurrences*	*Percentage of total prey weight*
Cottontail	400	3	37.1
Ground squirrel	180	5	27.9
Woodrat	200	3	18.6
Bird egg	8.5	20	5.3
Gopher	130	2	4.0
Other	variable	37	7.1
Totals		70	100.0

The high percentage of cottontail in this small sample may be unrepresentative. One giant gopher snake, nearly seven feet long, had eaten an adult cottontail which weighed as much as most of the smaller food items combined. Such incidents as this must be rare, and comparatively few gopher snakes are big enough to swallow any but nestling cottontail.

Discussion. The data set forth above suggest that the cottontail bears the brunt of predation pressure from most of the larger species of mammal, bird, and snake predators. The breeding season is long, and adult females may soon replace lost litters, or may normally rear two or more litters in a year, thus offsetting the heavy losses to natural enemies.

The summer population of adults and well-grown young after the breeding season amounting in 1939 to one per 1.2 acres, represents a rabbit-weight of about 670 grams per acre, a figure to be borne in mind in connection with measured predation factors.

Computation of the rabbit-weight per acre eliminated by predation has been attempted on the basis of the known or estimated population of each predator species, the normal daily food requirement, and the percentage of the food weight which rabbits comprise. The population of coyotes was computed at one to more than 300 acres; the fox population at possibly the same figure (or probably somewhat more), the red-tailed hawk at one to 160 acres; horned owl at one to 100 acres; rattlesnake $2\frac{1}{2}$ per acre; gopher snake .6 per acre. Reducing these figures to population density per acre and multiplying by the food requirement, and the percentage comprised by rabbit, we obtain the data presented in Table 8.

TABLE 8

Cottontail Weights Consumed by Predators

Kind of predator	Population per acre		Food requirement per day in grams		Food weight per acre per day		Food per acre per year		Percentage of prey weight of cottontail		Weight of cottontail per acre eliminated annually by predators
Coyote	.0033	x	600	=	1.98	x 365 =	722	x	45.4	=	328.0
Rattlesnake	2.5	x	2	=	5.00	x 365 =	1825	x	15.2	=	277.4
Horned owl	.010	x	120	=	1.20	x 365 =	437	x	61.1	=	267.0
Gopher snake	.6	x	2	=	1.2	x 365 =	438	x	37.1	=	162.5
Fox	.0033	x	300	=	.99	x 365 =	361	x	35.6	=	129.0
Red-tailed hawk	.0062	x	120	=	.74	x 365 =	270	x	24.2	=	65.0
Total											1228.9 grams

This summation does not include the rabbits eliminated by bobcats and badgers, but both are among the more important cottontail predators.

Thus it appears that predation annually might eliminate a rabbit-weight of about double the nonbreeding population of adults and well grown young present in summer. Admittedly, at each stage of the computation a substantial margin of error is probable so that the figures obtained cannot be considered more than a rough indication of the magnitude of losses to each kind of predator. If, in the food composition of a predator, the proportion of young were higher among cottontail than among other kinds of prey, the percentage of cottontail computed would be too high. However, it is probable that the proportion of young among the ground squirrel, woodrat, and gopher snake, in prey samples was fully as large as among cottontail. Each of these species has, like the cottontail, a high reproductive potential and a rapid population turnover with even greater differentials between young and adult weights, and they were the only ones other than cottontail comprising substantial percentages of the diet in any of the predators. The populations of predator species are variable according to time and place, and all of them are computed on a somewhat doubtful basis for application to the experimental range as a whole; for the red-tailed hawk and horned owl, however, the figures used represent the absolute minimum. For rattlesnakes, gopher snakes, coyotes, and especially foxes, the population figures are less definite. The average daily individual food consumption under natural conditions is somewhat speculative. This is especially so in the

case of the snakes, and the figure used is based on the average individual weight, assuming that each snake consumes twice its body weight during the growing season as suggested by data obtained from several kept in confinement. For the rattlesnake most feeding records were obtained in April and May when small cottontail are available—but from June through October rabbits are not breeding and their young have grown too large to be swallowed. Few feeding records were obtained for snakes during this latter two-thirds of their active season, as they are then secretive or nocturnal. But it may be surmised that kangaroo rats and gophers are then substituted for the young rabbits and squirrels taken in spring.

For the horned owl there is a probability that the numbers of cottontail assumed to have been eaten was too high, for, unlike the other prey species, the cottontail is large enough to furnish several owl meals. Thus one might be counted several times from its limb bones and vertebrae appearing in several pellets, whereas the other prey species were generally identified from skulls revealing accurately the actual numbers eaten.

The predation calculated is not necessarily too high; it seems entirely possible that the rabbits are adapted to withstand such pressure by virtue of high reproductive potential. Ingles (1941: 243-6) records an instance of a female marked soon after birth, which had matured and produced a litter of its own at the age of six months. Many of the young born early in the breeding season, in fall, may mature in time to produce litters before the breeding season is ended by the drought conditions of the summer. Females that are mature in the fall at the beginning of the breeding season might be expected to produce nine young apiece during the seven or eight months of green growth if the average of 3.6 young per litter and two or three litters annually mentioned by Orr (loc. cit.) is representative. Females which lose their litters early might produce an even greater number. The young at birth probably weigh around 30 grams, and upon leaving the nest from 11 to 14 days later, they have increased to several times this weight. Growth during subsequent weeks is extremely rapid (Fig. 52).

In recent years ecologists have tended to minimize the importance of predation factors in controlling vertebrate populations. Errington (1946) has summed up the literature of predation, and presents a fairly convincing case to show that "intraspecific self-limiting mechanisms basically determine the population levels maintained by the prey." "* * * the patterns revealed may look remarkably little influenced by variations in kinds and numbers of predators."

Concerning rabbits, Errington (op. cit. 154-155) states that though more tolerant of crowding without intraspecific strife, "they are by no means free from automatic mechanisms [determining their upper and lower population limits in a given habitat.] * * * again and again lagomorphs recovering from depressed levels show rapid population gains from one year to the next, the attentions of wild flesheaters notwithstanding."

The matter is not merely one of lagomorphs being prolific or of making their gains when enemies are either numerically or proportionally scarce, as there are too many instances of lagomorph populations apparently conforming to patterns, even despite pronounced differences in numbers of such able hunters as horned owls and foxes."

On the San Joaquin Range there is no direct evidence that predation actually holds the cottontail population to any given level. The situation is complex, however, because several common predators take large numbers of cottontail without being entirely dependent on them; all could probably adjust themselves to absence of cottontail by taking larger numbers of the abundant ground squirrels, woodrats, and other rodents. The predators also prey to some extent upon each other, at least hawks, owls, coyotes and foxes all prey upon both rattlesnake and gopher snake. Individual predators are long-lived as compared with their rabbit or rodent prey, and survive fluctuations in the populations of the latter. Even on areas of a few acres, the cottontail, or rodents, are not uniformly abundant but are concentrated where conditions of food and cover favor them; they are sensitive to changing weather conditions which result in expansion or contraction of their preferred ecologic niches, and their numbers change in response. Each species is, however, favored by a different set of conditions, so that increase in one kind is apt to be accompanied by a more or less compensatory decrease in another. The kangaroo rat, for instance, is favored by arid conditions with sparse vegetation and its peak in numbers on the Experimental Range followed a series of dry years. The ground squirrel is also favored by a sparse forage crop, whereas the cottontail prefers a habitat with thickets providing surface cover. Response to such conditions can be seen in the varying abundance of rabbits and rodents on different parts of the Range; on the ungrazed headquarters area, having chaparral thickets and rank growth of swale vegetation, cottontails are more numerous than elsewhere, squirrels and kangaroo rats less so.

While changes in abundance of both cottontails and predators are known to have occurred since 1935, records are too fragmentary to show either clear cut correlation or lack of it. Coyotes were first controlled in the winter of 1935-36, and 35 were trapped during a few weeks period. Nearly as many were caught in each of several succeeding years, but by 1939 the population was much reduced. In August, 1936, at the time they were still numerous, Kenneth A. Wagnon recorded in his field notes that cottontail were extremely abundant around the Experimental Range headquarters, where as many as 50 congregated on the lawns in the evening, and he speculated that this high rabbit population might be the attraction for the coyotes. The reduction of coyotes to a fraction of their former numbers did not result in any noticeable increase in rabbits. The hawk and owl populations have been stable, but rattlesnakes over the Experimental Range as a whole, have doubtless been somewhat reduced by the continual drain on their population imposed by human activity.

Intraspecific, self-limiting mechanisms in the cottontail population of the Experimental Range were not evident, either. It is doubtful whether any mortality results from intraspecific strife—no fighting or other evidence of intolerance was observed even when many rabbits were concentrated on a small area. Their food supply is subject to even heavier use by other herbivores, particularly domestic stock, so that the amount remaining at the end of the dry season is not determined primarily by the number of cottontail. Conditions of critical severity with respect to

availability of moisture may occur late in the dry season, for at this time cottontail congregate at water, and avidly seek any remaining succulent vegetation. Rabbits in situations where no water is available may compete severely with each other for preferred foods such as rushes, already so closely cropped as to be unavailable to grazing stock. For young in the nest, weather conditions may be critical and heavy rains may result in their death by chilling or even drowning.

So far as observed, however, actual mortality in nearly all instances involved predation, upon individuals which were not obviously handicapped or diseased and which were well provided with food and shelter. That is, they were not part of a surplus population crowded out into a precarious marginal existence in critical periods, as in cases cited by Errington (op. cit.).

"Vunerability" of the cottontail population may depend not so much on the conditions of food and shelter available to the rabbits as on the numbers of predators present and the relative availability to them of ground squirrels, woodrats, pocket gophers and kangaroo rats. At least it seems fairly certain that the medium to high populations of these several rodents make possible the existence of the predators which account for most of the rabbit mortality.

Disease. Evidence of disease was rarely noticed among the rabbits trapped, though nearly all of them were heavily infested with large fleas. On one occasion a cottontail died suddenly for no apparent reason when it was being removed from a trap, suggesting the possible existence of shock disease in the population, but no autopsies or laboratory tests were carried out to verify this hypothesis.

On February 7, 1941, a cottontail evidencing sluggish behavior was noticed, and it allowed an observer to approach within eight feet, then crawled into a rock crevice. It made no effort to escape when picked up and died two hours later. There was a swelling about the size of a walnut on the lower jaw, containing a yellowish white mass of cheesy consistency, and a slightly smaller inguinal swelling. The liver was somewhat darkened with well-separated yellowish spots on its surface. This rabbit had an unusually heavy infestation of fleas; it was estimated that there were at least 100 on its head alone. Other rabbits seen at this location on the same day and during subsequent weeks appeared to be normally healthy.

Herman and Jankiewicz (1943) examined 43 cottontails from the experimental range, and found coccidia infections prevalent; six different types were described. The infections did not appear to be acute and their effect on the rabbits is not known. Cottontail experimentally infected with *Eimeria stiedae,* a coccidial liver pathogen of domestic rabbits did not develop severe infections, as do domestic rabbits, suggesting partial immunity. The only ectoparasite recorded by these authors was a flea *(Ctenocephaloides felis).* The animals were shipped to these authors in Los Angeles and the ectoparasites were probably lost during handling prior to shipment. Internal parasites found by them included two intestinal protozoans *(Trichomonas, Chilomastix),* two nematodes *(Obeliscoides cuniculi* and *Nematodirus leporis),* and several cestodes *(Taenia pisiformis, Cittotaenia variabilis* and other species of the same genus and *Raillietaenia retractilis).*

Summary

The cottontail is abundant in open woodlands of the Sierra Nevada foothill belt in central California. At the San Joaquin Experimental Range it competes heavily with livestock in use of the vegetation. During the summer dry season, the rabbits took grain baits freely, but during the growing season they preferred succulent natural foods.

Knowledge of the changing seasonal bait acceptance is of practical value in connection with management operations. At times, locally, it may be desirable to remove, by poisoning, cottontail populations which are known to be diseased, or which are causing obvious damage to cultivated crops or range forage. More often it may be desirable to retain the cottontail population while removing certain harmful rodent species. Ground squirrels, for instance, are controlled by annual poisoning on many of the foothill ranges. Squirrel poisoning operations during the winter or spring months would result in relatively light losses to the cottontail population since grain bait is not especially attractive to the rabbits at that season; but summer or early fall squirrel poisoning might at the same time reduce the rabbit population even more drastically.

Live trapping and marking of rabbits through a three-year period resulted in 1,159 captures of 228 individuals, and indicated that these animals are attached to definite small areas. Diameters of "foraging areas" within which individual rabbits usually stayed were roughly perhaps 700 feet, but were variable and occasionally long foraging trips were made. Immature animals appear to range less widely than adults. Of 23 rabbits released at a distance from the point of capture, three made homing movements of 4,400, 3,550 and 3,150 feet respectively; 10 were recaptured near the place of release, and the others were not again recorded.

One rabbit was recorded to have shifted its range a distance of 3,300 feet. Such movements may be fairly common and important in the population turnover of small areas. Water and succulence in the dry season attract unusual concentrations of cottontails.

In censusing the population by the ratio of marked ones to others during the dry season of each year on the 80-acre study area, the following numbers were recorded: 1939, 153; 1940, 53; 1941, 95. Allowing for movements outside the 80 acres, the population density was calculated as one per 1.2 acres in 1939 and one per 2.6 acres in 1940. In its cottontail population, the 80-acre study area was below the average of the experimental range as a whole. Road counts over 1,754 acres of the experimental range compared with similar counts on the trapping area, indicated a population density for these pastures 1.7 times that of the study area.

Observations on the feeding habits indicated that in spring the common forage plants most used by cattle, soft chess, foxtail fescue, broadleaf filaree, popcorn flower, and gold fields, make up the bulk of the cottontail diet. Through the summer heavy use of soft chess continues, but as the forage crop in general dries out, there is a distinct tendency to concentrate on swale vegetation where succulence remains. Clovers, rush, and dock are swale plants especially sought at this time. Leaves, seeds, and stems of tarweed, and leaves and stems of turkey mullein are often taken in summer. These along with dock, constitute plants rather unpalatable to livestock, so that competition is somewhat reduced during

the dry season. Cast seeds of foxtail fescue constitute an important food source during the dry season.

Numerous wildlife species predatory on cottontails occur in the region of the experimental range. In order of their importance, predators included the coyote, rattlesnake, horned owl, gopher snake, gray fox, and red-tailed hawk. From the proportion of rabbit found for each species in the course of numerous scat, pellet, and stomach examinations, the population density of these predators, and the individual food requirement of each kind, it was estimated that predation factors annually might consume a cottontail weight of 1,229 grams per acre. This greatly exceeds the weight of the cottontail population actually present in late summer, before the breeding season begins. Nevertheless, the cottontail may be able to withstand this severe predation pressure by virtue of its long breeding season with possibly several litters of young annually for each adult female.

One diseased and dying rabbit was found, but no evidence was obtained that disease causes extensive mortality or affects population trends in this locality.

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DISTINCTIVE CHARACTERS OF THE SPECIES OF ANADROMOUS TROUT AND SALMON FOUND IN CALIFORNIA[1]

By Leo Shapovalov
Bureau of Fish Conservation
California Division of Fish and Game

Common and Scientific Names

Five species of salmon and two species of anadromous trout have been taken in California.[2] Our official common names for them and their scientific names are given in the following list:

Steelhead Rainbow Trout	*Salmo gairdnerii*
Cutthroat Trout	*Salmo clarkii*
King Salmon	*Oncorhynchus tshawytscha*
Silver Salmon	*Oncorhynchus kisutch*
Pink Salmon	*Oncorhynchus gorbuscha*
Chum Salmon	*Oncorhynchus keta*
Red Salmon	*Oncorhynchus nerka*

Some persons will recognize these fishes under other names. Other common names that have been used for the King Salmon are black salmon (applied to individuals that have become dark because of long presence in fresh water), chub salmon (applied to young males), dog salmon or hookbill (applied to males with hooked snouts), silver salmon (applied to young fish fresh from the ocean in the Sacramento River system), chinook salmon, spring salmon, quinnat salmon, and tyee salmon. Other common names applied to the Silver Salmon include jack salmon (applied especially to young males), dog salmon or hookbill (applied to males with hooked snouts and red sides), coho, and silversides. Other common names which are sometimes used for Steelhead Rainbow Trout include rainbow (applied to individuals that color up in fresh water without going to sea), half-pounder (applied to small sea-run individuals or large, silvery individuals that have remained in fresh or brackish water, weighing usually from one pound to two and one-half pounds, especially in the Eel River system), summer salmon (applied to sexually immature spring-run fish, especially in the Middle Fork of Eel River), salmon trout, steelhead, and steelhead trout. Pink Salmon are also known as humpback salmon, Chum Salmon as dog salmon, and Red Salmon as sockeye salmon or blueback salmon. The non-anadromous form of the latter, recently introduced into California, is known as the Kokanee, but elsewhere has also gone under the names little redfish and silver trout.

Distribution

The Steelhead Rainbow Trout is the most widely distributed of our anadromous salmonids, spawning in practically every coastal stream,

[1] Submitted for publication, April, 1947.
[2] Anadromous fishes are those which spend a portion of their lives in the ocean and then ascend streams to spawn.

small or large, that has not been rendered unfit by man, from the Oregon line to the Mexican border. The sea-going Cutthroat Trout is confined to the northermost portion of the State, to streams in Humboldt and Del Norte counties.

The King Salmon spawns extensively in the Sacramento-San Joaquin river system, although now blocked from the majority of its natural spawning grounds by dams, and in the larger streams to the north. The spawning range of the Silver Salmon in California is from some of the streams tributary to Monterey Bay to the Oregon line. Like the steelhead, it enters both large and small streams, but appears to be absent from the Sacramento-San Joaquin river system. The Pink Salmon spawns in some of the streams in Mendocino County, but these runs are irregular, and in the State as a whole the species is of minor importance both for angling and commercially. The other two species, the Chum Salmon and the Red Salmon, are only occasional visitors to our waters.

Living things are prone to provide us with exceptions, and so it is with trout and salmon. Individuals or small spawning runs of the various species have on occasion entered scattered streams outside their normal range. For example, King Salmon have been recorded from as far south as the Ventura River, in southern California.

The ocean range of at least the King Salmon extends to the south of its normal spawning range. The commercial catch in Monterey Bay has totaled millions of pounds annually, although spawning does not occur normally south of the Golden Gate.

Recognition of Specimens in Hand

Belonging to the same family of fishes, the Salmonidae, all of the species in general resemble each other, but possess certain characters by which they may be distinguished (Fig. 54).

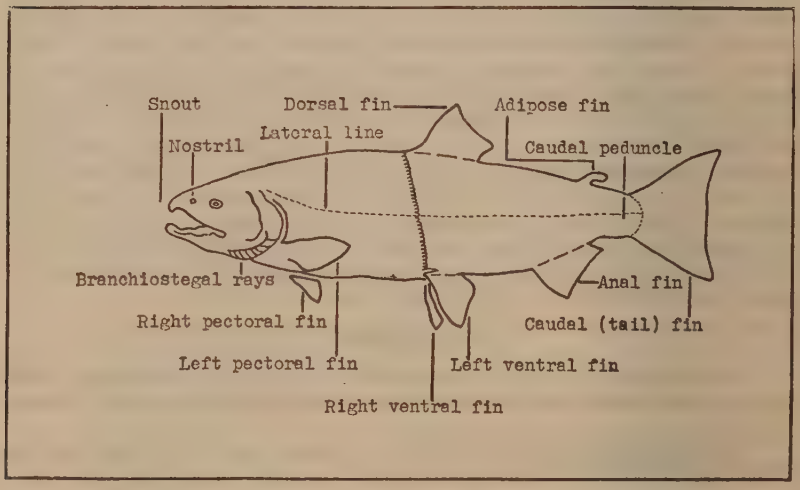

FIGURE 54. Diagram showing some of the external structures which are used in identifying salmon and trout

If the fish are in hand, the most useful characters for distinguishing sea-run trout from salmon for the layman and the angler unfamiliar with fish anatomy are the deep caudal peduncle and whitish mouth parts of the former, in contrast to the relatively slender caudal peduncle (Fig. 55) and blackish mouth parts of the salmon. It is difficult to pick up a steelhead or cutthroat by grasping the tail, but a salmon may be readily held in this manner. In addition, the caudal (tail) fin tends to be squarish in the trouts, while in the salmons it has an inward curve. Finally, the dorsal fin of adult salmon, except King Salmon, is plain or with dark blotches, but without definite spots, while the trouts possess definite blackish spots on the dorsals.

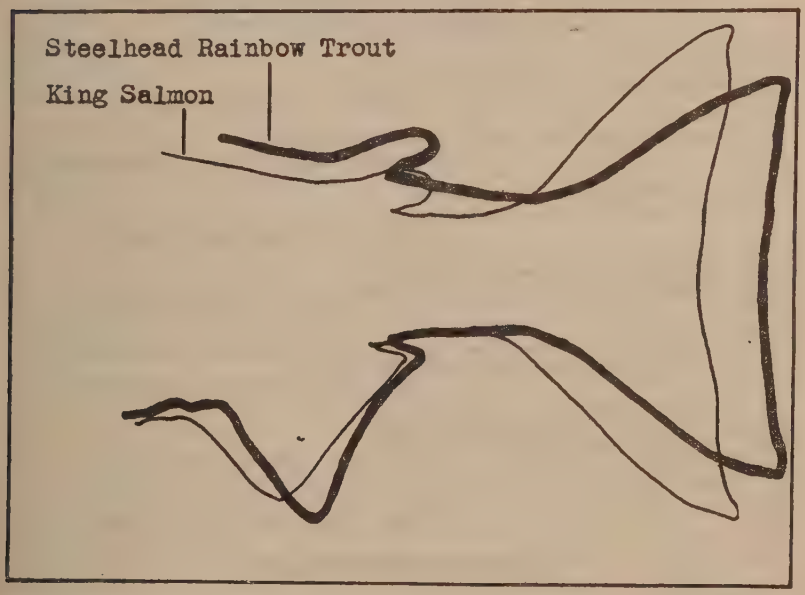

FIGURE 55. Outlines of the posterior portions of a steelhead and a salmon each of the same length, showing characteristic differences in depth of caudal peduncle and shape of caudal fin.

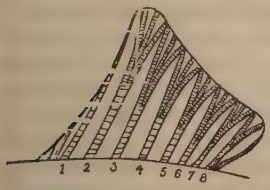

FIGURE 56. Diagram illustrating method used in counting dorsal and anal fin rays. The last ray is often branched at base and is counted as one.

Although the above general rules are useful, it is best to rely on the characters which remain unchanged throughout life, such as numbers of rays in different fins, oblique rows of scales crossing the lateral line (one such oblique row is shown in Fig. 54 but not labeled), pyloric caeca (the small, fingerlike appendages of the stomach), gill rakers, and branchiostegal rays, for definite recognition when the fish are in hand (See

FIGURE 57. Diagram of gill arch, showing gill rakers. The count includes the upper and lower halves of the arch. Always count all rudiments.

Figs. 54, 56, and 57). These characters are used in the following key, which is based on *alternate characters*. One character is given under 1a and the contrasting character under 1b, and so on through 2a and 2b and subsequent numbers. If your fish fits under 1a, proceed to 2a and 2b and choose between them. But if it fits under 1b, proceed to 3a and 3b and choose between them, and so on until you have placed your fish.

KEY TO THE SPECIES OF ANADROMOUS TROUT AND SALMON FOUND IN CALIFORNIA

1a. Rays in anal fin not more than 12. *Trouts.*
2a. Red dash in cleft under each side of lower jaw.
Cutthroat Trout, *Salmo clarkii.*

2b. No red dash in cleft under each side of lower jaw.
Steelhead Rainbow Trout, *Salmo gairdnerii.*

1b. Rays in anal fin more than 12. *Salmons.*
3a. Gill rakers 30 or more on first arch.
Red Salmon, *Oncorhynchus nerka.*

3b. Gill rakers fewer than 30 on first arch.
4a. More than 170 oblique rows of scales crossing the lateral line.
Pink Salmon, *Oncorhynchus gorbuscha.*

4b. Fewer than 170 oblique rows of scales crossing the lateral line.
5a. Pyloric caeca fewer than 100.
Silver Salmon, *Oncorhynchus kisutch.*

5b. Pyloric caeca more than 100.
6a. Rays in anal fin 13 or 14.
Chum Salmon, *Oncorhynchus keta.*

6b. Rays in anal fin 15 or more.
King Salmon, *Oncorhynchus tshawytscha.*

Recognition in the Water

Recognition in the water is more difficult, but must be used, for example, at counting stations. Here, general body form and coloration and configuration of different parts of the body must be relied upon. These characters vary not only with the species, but also with the sex, size, degree of sexual maturity, and length of stay in fresh water of the individual fish, so that experience is necessary to use them. The fish counter should check his identifications of fish in the water by dipping up individuals until he is sure that he is distinguishing his fish correctly. Since many California streams contain steelhead, King Salmon, and Silver Salmon, but only a few of any of the other species, the following discussion of field characters will place emphasis on the above-named three. The statements made are based on experience in California, but are set down advisedly, and all field workers are requested to inform the writer regarding those which are of little use or do not hold good under all conditions and in all localities, and also of any useful characters which have been omitted.

In general body form the trouts are slimmer than the salmons. In the salmon males the snout tends to become much more hooked, elongated, and deformed at spawning time than it does in the males of the trouts. Some King Salmon reach a larger size than is attained by any of the other salmonids, and may be distinguished on this basis alone. The pectoral fins of the Silver Salmon are relatively longer than those of the steelhead. The Silver Salmon usually has a more conical head than do either steelhead or King Salmon. It may also be distinguished from the other two, particularly the steelhead, by its white nostrils. As the season progresses, however, the nostrils of the King Salmon also tend to appear whitish.

At sea all species of salmon and trout take on a general silvery coloration, but after they enter fresh water and ripen sexually, they assume colors which are characteristic. The King Salmon of both sexes tend to become blackish, with dark coloration on the sides of the head. Little red color is shown by this species except in the large males, and even in these it never approaches the brilliancy that it does in Silver Salmon. The silver males often become quite red—usually a brick red—while the females become dull bronzy. In the steelhead the sides remain more or less silvery, but develop a broad flesh-colored or rosy lateral band or wash, brightest on the gill covers.

In the Pink Salmon, the spawning males become quite red, more or less blotched with brownish. The fleshy dorsal hump becomes much developed and the jaws exceptionally elongated and hooked. The females are olive-green on the sides, with dusky stripes. The breeding males of the Chum Salmon also become much distorted, with coloration generally blackish above, sides brick red, often barred or mottled, and fins blackish. In the Red Salmon, the spawning males possess brilliant red backs and sides, with the reddish color extending to most of the fins, under parts that are dirty white, and heads olivaceous above and on the sides. The mature females are dark red, with green and yellow blotches. The sea-run cutthroats are extremely variable in coloration and form. Generally, the color is olive green on the sides, darker green above, and silvery below. The sides of the head have a pinkish wash, and the lower fins are largely reddish orange.

Movements in the water of the different species tend to be characteristic. In jumping over a low obstacle, such as a counting board, both King Salmon and Silver Salmon tend to go over with a sort of rolling motion, while the steelhead tend to jump straight ahead. Similarly, in breaking water in a pool the salmons tend to come out with a rolling motion, while the steelhead usually come out with a straight thrust.

In some instances it has been noted that in leaping the salmons have extended their pectoral fins fully, while the steelhead have folded them partially against the body.

The sexes are best distinguished externally by the elongated snout of the males, by the "razor back" and generally slimmer appearance of the males, and by the generally cumbersome, roundish appearance of the females. These characters become marked only as the fish approach sexual maturity.

Recognition of Mutilated Specimens

Another type of problem in recognition is encountered by the law enforcement officer. Often he obtains as evidence a cleaned fish, or only part of a fish. To aid in identification in such cases, various characters possessed by the different species are here summarized and will prove useful if some of the needed characters given in the key are missing.

STEELHEAD RAINBOW TROUT: Rays in anal fin usually 9 to 12 (rarely 13); pyloric caeca 42 to 80; gill rakers 16 to 22 on first arch; branchiostegal rays 10 to 12; 115 to 180 oblique rows of scales crossing the lateral line; no red dash in cleft under each side of lower jaw evident in life; rays in dorsal fin 10 to 13 (usually 11 or 12); hyoid teeth (those located behind the patch of teeth on tip of the tongue) always absent. Maximum weight about 30 pounds.

CUTTHROAT TROUT: Rays in anal fin 9 to 11 (usually 10); pyloric caeca about 45; gill rakers 14 to 21 on first arch; branchiostegal rays 10 to 12; 120 to 180 (usually 150 to 160) oblique rows of scales crossing the lateral line; red dash in cleft under each side of lower jaw usually evident in life; rays in dorsal fin 8 to 11 (usually 10); hyoid teeth usually present but few and scattered. Maximum weight about 12 pounds.

KING SALMON: Rays in anal fin 15 to 19; pyloric caeca 93 to 214; gill rakers 20 to 31 on first arch; branchiostegal rays 13 to 19; about 135 to 155 oblique rows of scales crossing the lateral line; characterized by small black blotches on both lobes of tail. Maximum weight over 100 pounds, but individuals over 50 pounds are rare.

SILVER SALMON: Rays in anal fin usually 13 or 14 (rarely 12, 15, 16, or 17); pyloric caeca 45 to 83; gill rakers 19 to 25 on first arch; branchiostegal rays 11 to 15 (usually 13); about 120 to 145 oblique rows of scales crossing the lateral line; blackish spots on back as a rule smaller than those in King Salmon, and extending only to upper lobe of tail. Maximum weight about 27 pounds, but individuals over 15 pounds are rare.

PINK SALMON: Rays in anal fin 13 to 17; pyloric caeca 165 to 195; gill rakers 26 to 35 on first arch; branchiostegal rays 9 to 15; about 170 to 240 oblique rows of scales crossing the lateral line; large and oblong blackish blotches on caudal fin. Maximum weight about 10 pounds.

CHUM SALMON: Rays in anal fin 13 to 17 (rarely 12); pyloric caeca 135 to 185; gill rakers 19 to 26 on first arch; branchiostegal rays 10 to 16 (usually 13 to 15); about 120 to 153 oblique rows of scales crossing the lateral line; back and sides with no defined spots. Maximum weight about 30 pounds, but individuals over 15 pounds are uncommon.

RED SALMON: Rays in anal fin 13 to 17 (usually 14 or 15); pyloric caeca 66 to 95; gill rakers 30 to 50 on first arch; branchiostegal rays 11 to 15; about 125 to 145 oblique rows of scales crossing the lateral line. Maximum weight about 16 pounds, but individuals over 8 pounds are rare.

NOTES

RARE FISHES TAKEN NEAR LOS ANGELES

The following list of fishes is made up from records of those rare and unusual fishes turned over to or acquired by the California State Fisheries Laboratory since the last list published in "California Fish and Game," by Daugherty, Vol. 32, No. 3, pp. 157-158, July, 1946.

Lathrypnus dalli (Gilbert). Goby: A specimen approximately one inch in length was taken September 15, 1946, at Emerald Bay, Santa Catalina Island, in about 20 feet of water by T. S. Davis of Hermosa Beach. Mr. Davis while skin diving brought up a barnacle-encrusted beer bottle with the goby living inside. The fish was too large to be removed from the bottle and only after it had been dead a couple days and shrunk in size was it removed without breaking the bottle. This species attains a length of one and one-quarter inches and has been reported from Santa Catalina Island in waters as deep as 300 feet. In life this goby is a very beautiful fish with a bright coral red body bearing several vertical blue bands which almost meet on the ventral side. Blue streaks and bands also occur on the head and around the eyes.

Luvarus imperialis (Rafinesque). Louvar: On September 29, 1946, S. E. Edmundson, operator of the mackerel scoop boat *"Nahra"* brought in the anterior portion of a femal louvar which had been found floating on the surface of the ocean approximately 10 miles southwest of Santa Catalina Island. It had been cut off just behind the insertion of the dorsal fin, was about two feet long and weighed 48 pounds. The mutilation may have been the result of sharks attacking the fish. Several louvars have been taken on the coast from as far north as Monterey but little is known of the life hisitory or activities of this strange and rare visitor to our coast. It has previously been reported in "California Fish and Game" by the following authors: Bolin, Volume 26, Number 3, pp. 282-284, 1 figure, 1940; Croker, Volume 25, Number 3, pp. 252-254, 1939; and Thompson, W. F., Volume 5, pp. 202-203, 1919.

Enophrys taurinus (Gilbert). Cottid: This quite rare fish was found in a load of sardines on the San Pedro seiner *"Clermont"* which made the catch on December 20, 1946, halfway between Santa Cruz and Santa Rosa Islands in 30 or 40 fathoms of water. The specimen, approximately four inches in length, had red coloring on the pectoral and pelvic fins which has not been reported in previously described individuals.

Verrunculus polylepis (Steindachner). Trigger Fish: A specimen caught in a trammel net December 23, 1946, just north of the San Clemente pier, was turned over to the laboratory by Morris Souder and Emery S. (Casey) Jones of the Bayside Fish Market, Newport. The fish was approximately one foot long, though the species attains a length of two and one-half feet. It is numerous in Lower California waters but only a rare visitor as far north as San Pedro. The trigger mechanism of this species is described by Clothier in "California Fish and Game," Volume 25, Number 3, pp. 233-236, 1940.

Ruvettus pretiosus (Cocco). Oilfish: One specimen turned over to the laboratory by the skipper and crew of the seiner *"Sparton"* was caught in a blufin tuna haul near Guadalupe Island, Lower California, in 50 fathoms of water January 28, 1947. The fish was 49 inches in length and weighed 34 pounds. This is apparently the second known record of this species from the eastern Pacific. It has also been recorded from the two sides of the Atlantic, the East Indies, Hawaii, Japan, South Africa, and various South Sea Islands. The other specimen is recorded from our coast by Barnhart and Hubbs in "California Fish and Game," Volume 30, Number 1, pp. 52-53, 1 illustration, 1944.

Figure 58. Young Black Sea-bass, *Stereolepis gigas*. Photo by Haden and Carpenter, San Pedro

Stereolepis gigas (Ayres). Black Sea-bass; Jewfish: A small black sea-bass, approximately three and one-half inches long, was found in a load of Pacific mackerel taken by the seiner *"St. Augustine"* about seven miles off the town of San Clemente on the night of February 24, 1947. The black sea-bass known to most people is a veritable giant of a more or less dull blackish color. This young specimen was a brick red color with black spots over the body which gave a polka-dot effect. Local fishermen report that they often see young black sea-bass in and around the kelp beds. A decription of the change in color and form which occur with growth in this species is given by Higgins in "California Fish and Game," Volume 6, Number 1, pp. 5-6, illustrated, 1920.

John E. Fitch, Bureau Marine Fisheries,
California Division Fish and Game, March, 1947.

IN MEMORIAM

JOHN H. DAVIS

John H. Davis, probably the oldest of the old-timers of the California Fish and Game Commission, died early in 1947 in San Francisco at the age of 90.

For approximately 25 years, spanning the centuries, Mr. Davis served as a deputy. He was a license collector from Crescent City to San Diego and later was on the patrol boats. It is said he named the first "*Quinnat*" and it is known he was her first skipper.

Mr. Davis told many interesting stories of exciting experiences in his work for the commission. One related how he hid on shore, in the midnight darkness, under the willows of the Noyo River, to reach out and nab Phil Roselle, an early-day poacher as he came singing in his boat to take in his illegal net. When Roselle, described by Mr. Davis as the "arch-conspirator of the Noyo" went to the county jail to serve his time, the sheriff regretted the end of his sentence, because he turned out to be the best cook the jail ever had!

At another time Mr. Davis stopped a Salvation Army parade on San Francisco's Embarcadero to arrest the bass drummer, whom he recognized as a wanted violator. The band played on without its big drum.

With horses and wagon, he hauled hatchery trout in milk cans from the railroad at Merced to plant them in the waters of Yosemite. He directed the planting of black bass in the Russian River.

A postmaster in the Napa district tipped him off that he could find out-of-season hunters in a nearby area. Davis went to another area and found that same postmaster violating the game law.

Mr. Davis had many friends among the older commercial fishermen. In later years, after retirement, one of his great joys was to visit Fisherman's Wharf at San Francisco and hobnob with the first-generation crab fishermen, talking Italian and waving his arms, too. He could speak Spanish, Portuguese and seven Italian dialects.

A Chinese fisherman testified falsely against Mr. Davis in court. Later, when the latter chugged up in the patrol boat to visit the Oriental's camp at McNear's Point, the conscience-stricken Chinaman hid in a shack during the deputy's stay. The man was ostracized by his fellows.

John Davis served under four California Governors—James H. Budd, Henry T. Gage, George C. Pardee, and Hiram W. Johnson. On the commission he served under John P. Babcock and Charles A. Vogelsang, Chief Deputies; and worked with Manuel Cross, Hugh Walters, Walter Welch, and Alonzo Lea, brother of Congressman Lea.

For many years he resided at San Pablo, California, where, for a period, he was constable. Family tradition has it his father and mother were the first white couple married in Oakland. He was born at Stege.

Mr. Davis retired some 40 years ago and is survived by eight daughters, eight grandchildren, and eight great grandchildren. His wife preceded him in death in 1940.—*Samuel Hawkins, San Francisco, March, 1947.*

GEORGE NEALE

George Neale, former employee and executive officer of the Division of Fish and Game, passed away at his home in Sacramento, November 30, 1946.

Mr. Neale was born in London, England, October 9, 1857. He came to the United States in 1876 making his home in Sacramento where he engaged in private business. He was naturalized in Sacramento in July, 1880, by Judge Denson of the superior court.

Always an ardent hunter and fisherman, he was interested in the protective laws and was made county game warden in Sacramento in January, 1903. A few weeks later, in April, he was given an appointment as warden by the then Chief Deputy, Charles A. Vogelsang.

With the appointment of Frank Newbert on the commission in 1911, Neale was placed in charge of the Sacramento office and in March, 1922, was appointed executive officer, resigning in December, 1925. He again entered the service of the division in August, 1928, and later was put in charge of the Bureau of Fish Rescue work, resigning in August, 1934.

He is survived by his widow, Ada Roberts Neale, and by several nieces in England.—*J. S. Hunter, Chief, Bureau of Game Conservation, California Division of Fish and Game, May, 1947.*

WALTER R. KRUKOW

On April 20, 1947, while on patrol duty on Boulder Creek, 16 miles west of Redding, Fish and Game Warden Walter R. Krukow was shot and instantly killed by Sanford L. Johnson, a 17-year old high school student who was fishing for trout during the closed season.

According to the youth's own statement, the warden warned him to cease fishing and to wait until the first of May, the legal opening date. Johnson then traveled several miles on foot to his residence, procured a rifle and ammuniton and returning to Boulder Creek shot Warden Kurkow from ambush to prevent the arrest of his fishing partner for a similar game law violation. The youth is in jail at Redding awaiting trial.

Walter R. Krukow was born at San Pedro, California, on May 28, 1905, and graduated from Glendale High School. He went into business for himself as a landscape gardener prior to joining the division March 23, 1937, as an assistant warden. He served in Southern California prior to his assignment in Shasta County and was promoted warden March 1, 1944.

He leaves a widow, a young son and an infant daughter in Redding, as well as a sister in Southern California. To these innocent victims of a needless tragedy we wish to extend our deepest sympathy.—*E. L. Macaulay, Chief, Bureau of Patrol, California Division of Fish and Game, June, 1947.*

REPORTS

FISH CASES

January, February, March, 1947

Offense	Number arrests	Fines imposed	Jail sentences (days)
Abalone: taking from shell below high water, taking to sell commercially, undersized, overlimit, no license	85	$2,450 00	
Angling: using set lines, no license, more than one rod, possession gaff 300 feet stream, illegal net, within 150 feet dam, closed area, near fish ladder, transfer license, with hand line	167	3,722 50	750
Bass: undersize, overlimit, more than one rod, night fishing, possession for sale	59	1,007 50	
Catfish: undersized, overlimit, selling and purchasing, undersized	2	525 00	
Crappie: Overlimit	3	50 00	
Clams: undersized, overlimit, without license, in refuge	99	2,762 00	491½
Commercial: no license; receiving and selling fish taken closed season; gill net Dist. II; purse seine Dist. XX; failure to keep trawler log; untagged fish	12	2,025 00	
Crabs: undersize, taking on Sunday	23	1,930 00	
Lobster: closed season, undersize, traps, closed district, oversize	12	215 00	
Pollution	6	350 00	
Salmon: undersize, within 150 feet of dam, snagging, taking in spawning area, shore limit, spearing, spearing closed area, drift gill net, shooting, gaffing, illegal possession, taking in Dist. XII	13	810 00	
Sunfish: closed season	3	75 00	
Trout: untagged, overlimit, set lines, chumming, closed area, closed season, snagging, with spear at night	44	1,460 00	6
Totals	528	$17,382 00	528½

GAME CASES

January, February, March, 1947

Offense	Number arrests	Fines imposed	Jail sentences (days)
Beaver	1	$50 00	
Coots: Closed season	8	200 00	
Deer: closed season, illegal possession, unmarked, female, spike buck, take in refuge, altering tag, transferring tag, spotlighting, killing fawn, taking forked horn, 22 rifle	35	4,105 00	500
Deer meat: illegal possession, unstamped	45	3,121 00	139½
Doves: Closed season, overlimit, no license	4	200 00	
Ducks: Closed season, overlimit, shooting from motor boat, offering for sale, game refuge, with 22 rifle, after hours	87	3,607 50	
Grebe	1	10 00	
Geese: overlimit, with automobile, after legal hours, with shotgun	17	770 00	
Grey squirrel	6	125 00	
Hunting: no license, night hunting with spotlight, from motor vehicle, unplugged gun, in refuge, closed season, citizen's license, shooting from motor boat, after legal hour, nonresident with resident license	105	2,714 00	3
Non-game birds	14	655 00	30
Pheasants: hen, closed season, no license, shooting from automobile, before hours, taking with gun holding more than three shells	70	4,332 00	191
Quail: closed season, overlimit	16	435 00	
Rabbits: taking at night, closed season, no license, operating snares	31	950 00	
Shore birds	2	60 00	
Swans	3	75 00	
Taking fur bearing mammals without license	2	65 00	
Trapping: no license, nonresident	5	55 00	
Totals	452	$21,529 50	863½

SEIZURES OF FISH AND GAME

January, February, March, 1947

Fish	
Abalone	549
Abalone, pounds	1,237½
Bass	56
Bass, pounds	734
Catfish, pounds	150
Clams	1,327
Crab	180
Crappie	14
Lobster	128
Lobster, pounds	424½
Salmon	7
Trout	38
Trout, pounds	2,027
Game	
Coots	21
Deer	11
Deer, pounds	1,158
Doves	10
Ducks	107
Geese	58
Non-game birds	9
Pheasants	49
Quail	98
Rabbits	20
Shorebirds	4

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(Continued from inside front cover)

BUREAU OF GAME CONSERVATION

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Donald D. McLean, Game Biologist—San Francisco
John E. Chattin, Game Biologist—Berkeley
R. E. Curtis, Game Manager—San Francisco
Carlton M. Herman, Parasitologist—Berkeley
John R. Wallace, Supervisor, Predatory Animal Control—San Francisco
C. Van Ornum, Supervisor, Game Farms—San Francisco
William P. Dasmann, Game Range Technician—San Francisco
Howard Twining, Assistant Game Biologist, Federal Aid Project 22R—Chico
Henry A. Hjersman, Assistant Game Biologist, Federal Aid Project 24R—San Francisco
Daniel F. Tillotson, Assistant Game Biologist, Federal Aid Project 25R—Berkeley
Arthur L. Hensley, Assistant Game Manager, Fur Management—San Francisco
David M. Selleck, Assistant Game Manager—King City
Russell M. Bushey, Assistant Game Manager, Madeline Plains Waterfowl Management Area—Madeline
L. H. Cloyd, Assistant Game Manager, Gray Lodge Refuge—Gridley
J. S. Dow, Assistant Game Manager, Elk Refuge—Tupman
Verne F. Fowler, Assistant Game Manager, Honey Lake Waterfowl Management Area—Wendel
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John N. Laughlin, Assistant Game Manager—Riverside
Ralph R. Noble, Assistant Game Manager, Suisun Refuge—Suisun
Russell M. Reedy, Assistant Game Manager, Imperial Refuge—Calipatria
James D. Stokes, Assistant Game Manager—Alturas
Roy M. Wattenbarger, Assistant Game Manager, Los Banos Refuge—Los Banos
Gerald McNames, Supervising Trapper—Redding
Norval Jeffries, Supervising Trapper—Monrovia
O. R. Shaw, Supervising Trapper—King City
Geo. D. Seymour, Supervising Trapper—Sacramento
Val. H. Francis, Superintendent, Los Serranos Game Farm—Chino
E. D. Platt, Superintendent, Yountville Game Farm—Yountville

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W. L. Scofield, Senior Aquatic Biologist—Terminal Island
J. B. Phillips, Associate Aquatic Biologist—Pacific Grove
Wm. E. Ripley, Associate Aquatic Biologist—Stanford University
Paul Bonnot, Assistant Aquatic Biologist—Stanford University
Charles R. Clothier, Assistant Aquatic Biologist—Terminal Island
H. C. Godsil, Assistant Aquatic Biologist—Terminal Island
John F. Janssen, Jr., Assistant Aquatic Biologist—Terminal Island
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Phil M. Roedel, Assistant Aquatic Biologist—Terminal Island
Geraldine Conner, Fisheries Statistician—Terminal Island

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R. Nickerson, Supervising License Agent—Los Angeles
Emil Dorig, License Agent—San Francisco
Lois Guyette, License Agent—Fresno
Enid Mullens, License Agent—Redding

ACCOUNTS AND DISBURSEMENTS

D. H. BLOOD, Deputy Director and Comptroller—Sacramento
E. ARONSTEIN, Accounting Officer—Sacramento